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HULLBORNE HYDROFOIL SIX-DEGREE OF FREEDOM MOTION PREDICTION COMPUTER PROGRAM

by

R. Stahl

and

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SEP 16 1977

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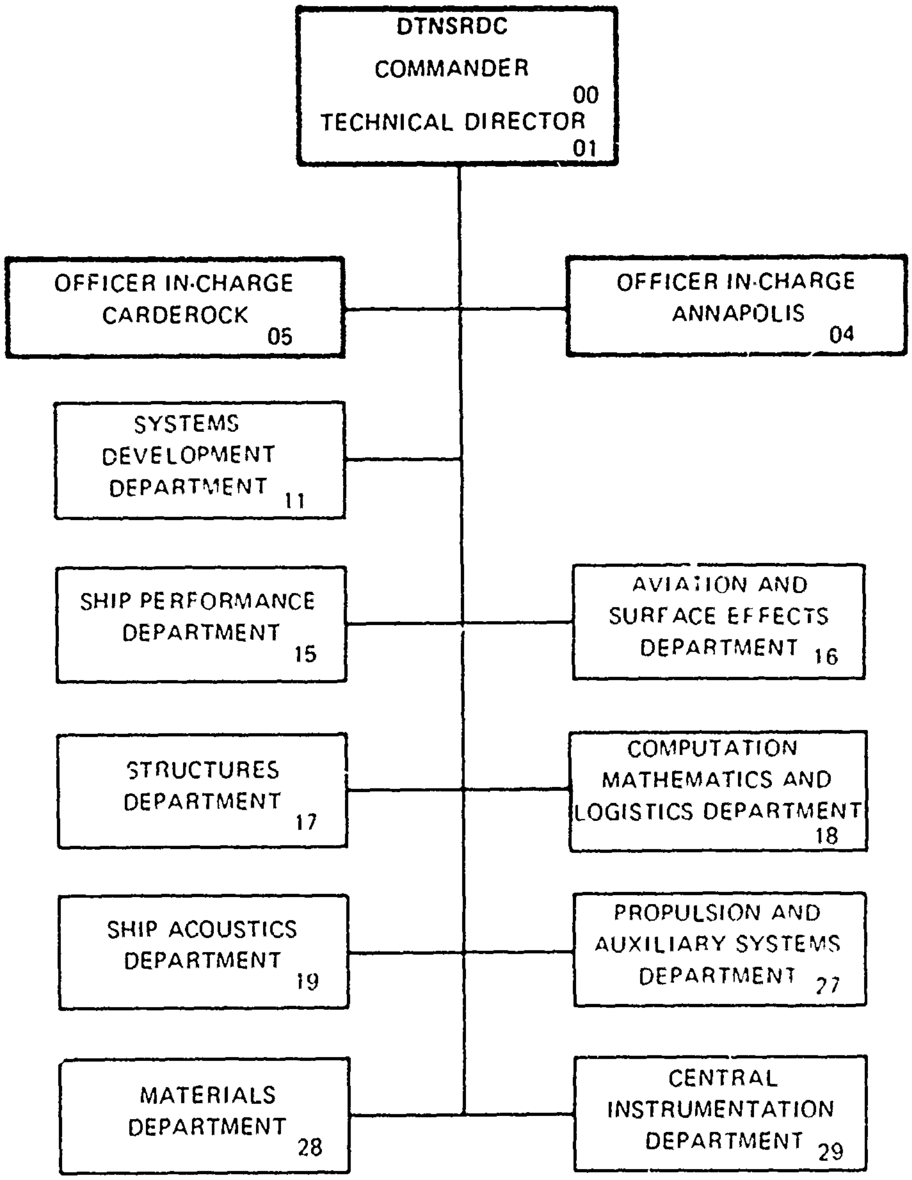

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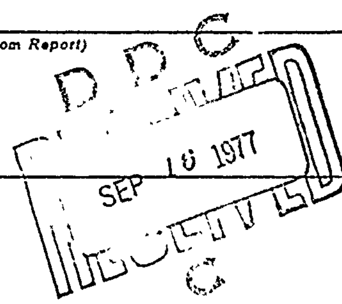

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A description of a motion prediction computer program for a hullborne hydrofoil is presented. This program computes the six-degree-of-freedom (6DOF) hydrofoil craft motions for a craft advancing at a constant forward speed, less than the critical "lift-off" speed, with arbitrary heading in regular waves. The structure of the program consists essentially of the already existing "DTNSRDC Ship-Motion and Sea-Load Computer Program" modified to incorporate the foil and strut system of a hydrofoil craft. Presented in this report is a brief discussion of the mathematical model, input information

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pertaining to the hydrofoil and a discussion of the results. The Appendicies present a listing of the foil coefficients, data card format description for the original program, and a program listing.

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NOMENCLATURE

A_{jk}	added mass coefficient
B_{jk}	damping coefficient
C_{jk}	restoring coefficient
$C_{L\alpha}$	lift curve slope
$C(k)$	Theodorsin's function
F_j'	excitation force or moment on a single foil element
F_j	exciting force or moment of hydrofoil system
I_j	moment of inertia
I_{jk}	product of inertia
K_2	wave number
L	total lift on foil element
$\bar{M}$	moment on foil element
U	ship speed
V_N	normal velocity on foil element
W_o	orbital wave velocity normal to foil element
Z_G	VCG in body system
X, Y, Z	foil element's midpoint in body frame
a_j	motion amplitude
b	span of foil element
c	chord of foil element
g	gravitational acceleration
h	depth of foil element

l	lift on foil of infinitesimal span
k	reduced frequency
m	mass
m_{jk}	generalized mass
$\bar{n}$	unit vector normal to foil element's midpoint
$\bar{r}$	position vector in body fram
t	time variable
v	velocity in body system
v_o	velocity in inertial system
x, y, z	body coordinate system
x_o, y_o, z_o	inertial coordinate system
Γ	dihedral angle of foil element
Ω	angular rotational velocity
ε_j	phase lag
	wave amplitude
η_j	motion displacement
λ	wavelength
μ	heading angle
ρ	water density
ω	wave frequency
ω_e	wave encounter frequency

ABSTRACT

A description of a motion prediction computer program for a hullborne hydrofoil is presented. This program computes the six-degree-of-freedom (6DOF) hydrofoil craft motions for a craft advancing at a constant forward speed, less than the critical "lift-off" speed, with arbitrary heading in regular waves. The structure of the program consists essentially of the already existing "DTNSRDC Ship-Motion and Sea-Load Computer Program" modified to incorporate the foil and strut system of a hydrofoil craft. Presented in this report is a brief discussion of the mathematical model, input information pertaining to the hydrofoil and a discussion of the results. The Appendicies present a listing of the foil coefficients, data card format description for the original program, and a program listing.

ADMINISTRATIVE INFORMATION

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INTRODUCTION

A description of the "DTNSRDC Hullborne Hydrofoil Motion Prediction Computer Program" is presented in this report. It predicts the motions for a hullborne hydrofoil craft in six-degrees-of-freedom (6DOF) advancing at a constant forward speed in the displacement mode with foils extended, at an arbitrary heading in unidirectional regular waves. The program is an adaptation of the already existing "DTNSRDC Ship-Motion and Sea-Load Computer Program", based on the theory by Salvesen, Tuck, and Faltinsen[1*] which was developed for the prediction of the motions and dynamic loads of conventional displacement type hulls and is utilized for planing hulls in the displacement mode as well. The program modifications consist basically of the insertion of the equations of motion for the foil and strut system of a hydrofoil vessel. The linearized hydrofoil terms, derived by the incorporation of Theodorsen's unsteadiness effects into a three dimensional quasi-steady formulation are superimposed on the already computed hull excitation forces, added mass, damping and restoring terms. This technique has been successfully used by R. T. Schmitke who developed two computer programs which determine the motions of a hullborne hydrofoil in single headings; one in head seas[2] and the second in beam seas.

The hull related input information for the modified program remains identical to the original program, "DTNSRDC Ship-Motion and Sea-Load Computer Program"[3]. The remaining required input all pertains to the strut-foil system.

*References are listed on page 21.

The modified program output presents, as in the original program for ship-motions, the amplitudes and phases in surge, sway, heave, roll, pitch and yaw for a given set of wave frequencies and a specified set of forward ship speeds and headings. Optionally, one can obtain the two sets of coupled differential equations of motion in matrix form; one for surge, heave, and pitch and the other for sway, roll and yaw. Each set is given for the hull portion, the foil-strut portion, the combination of the two, and the final inverted matrix with the solutions. Both sets are for the minimum specified frequency.

MATHEMATICAL MODEL

BASIC ASSUMPTIONS AND LIMITATIONS

The analytical model for determining the motions of a hullborne hydrofoil craft is derived by adding linearized hydrofoil terms to the strip theory obtained hull terms. The major assumptions and limitations are:

(1) the craft is traveling in a straight line at a constant forward speed and arbitrary heading in unidirectional regular waves

(2) the craft responds linearly and harmonically to regular wave excitation

(3) wave excitation amplitudes are small with correspondingly small craft displacement amplitudes from equilibrium

(4) all viscous effects are negligible except for the hull portion of the craft in roll

(5) both the craft's beam and draft are much smaller than its length

(6) the craft is laterally symmetrical

(7) dynamic lift attributable to the hull's planing surfaces is insignificant

(8) interaction between the hull and hydrofoil system is negligible as is the interaction between the foil elements

(9) the hydrofoil system's contribution to craft surging is negligible

(10) the foil system is divisible into a set of rectangular foil elements.

EQUATIONS OF MOTION

The conventions used in the hullborne hydrofoil craft motion program are the same as the "DTNSRDC Ship-Motion and Sea-Load Computer Program". The following will briefly restate the definitions used.[3] As shown in Figure 1, the vessel oriented,right-handed coordinate system is defined to have its origin in the plane of the undisturbed free water surface. The positive z axis is vertically upward passing through the craft's center of gravity, and the positive x axis passes through the craft's stern. The vessel is considered to be traveling at a constant forward speed (the negative x direction) with arbitrary heading in regular sinusoidal waves. The heading angle μ is defined to be 0 degrees for following waves and 180 degrees for head waves as illustrated in Figure 2. Encounter frequency ω_e to which the vessel will respond is

$$\omega_e = \omega - \frac{\omega^2 U}{g} \cos \mu \qquad (1)$$

Where U is the forward speed of the ship, circular wave frequency $\omega=\sqrt{2\pi g/\lambda}$, g is the gravitational acceleration, and λ is the wavelength.

With the assumption that the motions are linear and harmonic, the motion displacements are

$$\eta_j = a_j \cos(\omega_e t - \varepsilon_j); \; j = 1, \ldots, 6 \qquad (2)$$

where a_j is the amplitude and ε_j is the phase lag of the motion with respect to the maximum wave elevation above the origin. The subscripts j = 1...6, refer respectively to the translatory displacements of surge, sway, and heave and the angular displacements of roll, pitch, and yaw. Following from the above assumptions, the six linear coupled differential equations of motion can be written in complex form as:

$$\sum_{k=1}^{6} [(m_{jk} + A_{jk}) \ddot{\eta}_k + B_{jk}\dot{\eta}_k + C_{jk}\eta_k] = F_j e^{-i\omega_e t}; \; j = 1,\ldots 6 \qquad (3)$$

where m_{jk} are the components of the craft's generalized mass matrix, A_{jk} are the added-mass coefficients, B_{jk} and C_{jk} are the complex damping and restoring coefficients and F_j are the complex amplitudes of the exciting forces and moments.

For a hullborne hydrofoil craft as well as for a conventional displacement hull the six coupled equations of motion can be separated into two sets of equations. With the exclusion of hydrostatic restoring coefficients that are equal to zero for both the hull and foil system,

the first set of three coupled equations of motion in surge, heave, and pitch are

Surge
$$(A_{11} + m)\ddot{\eta}_1 + B_{11}\dot{\eta}_1 + A_{13}\ddot{\eta}_3 + B_{13}\dot{\eta}_3 + A_{15}\ddot{\eta}_5 + B_{15}\dot{\eta}_5 = F_1 e^{-i\omega_e t} \tag{4}$$

Heave
$$A_{31}\ddot{\eta}_1 + B_{31}\dot{\eta}_1 + (A_{33} + m)\ddot{\eta}_3 + B_{33}\dot{\eta}_3 + C_{33}\eta_3 + A_{35}\ddot{\eta}_5 + B_{35}\dot{\eta}_5 + C_{35}\eta_5 = F_3 e^{-i\omega_e t} \tag{5}$$

Pitch
$$A_{51}\ddot{\eta}_1 + B_{51}\dot{\eta}_1 + A_{53}\ddot{\eta}_3 + B_{53}\dot{\eta}_3 + C_{53}\eta_3 + (A_{55} + I_5)\ddot{\eta}_5 + B_{55}\dot{\eta}_5 + C_{55}\eta_5 = F_5 e^{-i\omega_e t} \tag{6}$$

and the second set of equations are

Sway
$$(A_{22} + m)\ddot{\eta}_2 + B_{22}\dot{\eta}_2 + (A_{24} - mZ_G)\ddot{\eta}_4 + B_{24}\dot{\eta}_4 + C_{24}\eta_4 + A_{26}\ddot{\eta}_6 + B_{26}\dot{\eta}_6 + C_{26}\eta_6 = F_2 e^{-i\omega_e t} \tag{7}$$

Roll
$$(A_{42} - mZ_G)\ddot{\eta}_2 + B_{42}\dot{\eta}_2 + (A_{44} + I_4)\ddot{\eta}_4 + (B_{44} + B_{44}^{*})\dot{\eta}_4 + C_{44}\eta_4 + (A_{46} - I_{46})\ddot{\eta}_6 + B_{46}\dot{\eta}_6 + C_{46}\eta_6 = F_4 e^{-i\omega_e t} \tag{8}$$

Yaw
$$A_{62}\ddot{\eta}_2 + B_{62}\dot{\eta}_2 + (A_{64} - I_{46})\ddot{\eta}_4 + B_{64}\dot{\eta}_4 + C_{64}\eta_4 + (A_{66} + I_6)\ddot{\eta}_6 + B_{66}\dot{\eta}_6 + C_{66}\eta_6 = F_6 e^{-i\omega_e t} \tag{9}$$

where m is the vessel's mass, Z_G is the location of the vertical center of gravity on the z axis, I_j is the moment of inertia in the jth mode, and I_{jk} is the product of inertia. B^*_{44} in the roll equation is the nonlinear viscous damping attributable to the hull. It is in the form of a quasi-linear function in terms of ω_e, viscosity, hull geometry, and the maximum roll amplitude for a given wave slope, speed V, and heading μ. The second set of equations in sway, roll, and yaw may have to be solved a number of times until the difference between the maximum estimated roll angle and the computed maximum roll angle is within an acceptable tolerance. In the program the allowed tolerance is one degree.

With the assumed insignificance of the hull and foil system interaction, the hull and foil system contribution to the added mass, damping and restoring coefficients and the forcing functions are simply additive. For example the added mass coefficients A_{jk} can be expressed as

$$A_{jk} = A^H_{jk} + A^F_{jk} \tag{10}$$

where A^H_{jk} is the hull added mass and A^F_{jk} is the frequency independent foil system added mass.

The derivation of the hull added mass, damping and hydrostatic restoring coeffficients and the exciting forces and moments used in the "DTNSRDC Ship-Motion and Sea-Load Computer Program" are presented as three-dimensional hydrodynamic quantities in Reference 1. Based on strip theory, these quantities are in turn expressed in terms of the solution to the sectional two-dimensional problem of each cylinder oscillating in the free surface. The sectional two-dimensional problem is solved by a close-fit source-distribution method presented in Reference 4.

HYDROFOIL COEFFICIENTS

The foil coefficients for nonzero forward speed are derived from Theodorsen's solution of the two-dimensional thin aerofoil oscillating in an incompressible fluid in pitch and heave with the inclusion of finite span and free-surface correction factors (see Reference 5). This method was used successfully by Schmitke in Reference 2 in predicting both the pitch and heave motions of a hullborne hydrofoil vessel in head seas in one case and the motions of roll, sway, and yaw in beam seas in the second case.

Utilizing Theodorsen's solution, consider first the submerged foil system of a hydrofoil craft as being comprised of individual foil elements. Each element is considered as a plane rectangle with no interaction between the elements. The lift force acting on a single foil element at its midpoint (point of intersection of the mid-chord and mid-span) is

$$\bar{L} = \bar{L}_{NC} + \bar{L}_{C} \tag{11}$$

$$\bar{L}_{NC} = \pi \rho (c/2)^2 \, b \, \dot{\bar{V}}_{N1/2} \tag{12}$$

$$\bar{L}_{C} = 0.5\rho Ubc \, C_{L\alpha} \, C(k) \, \bar{V}_{N3/4} \tag{13}$$

with c as the chord of the foil element

b as the span of the foil element

U as the forward craft speed

$C_{L\alpha}$ as the lift curve slope

$\dot{\bar{V}}_{N1/2}$ is the time derivative of the normal velocity component at the foil element's midpoint

$\bar{V}_{N3/4}$	is the downwash at the 3/4 chord
$\bar{L}_{NC}$	is the noncirculatory lift force or added mass term
$\bar{L}_{C}$	is the circulatory lift force consisting of dynamic angle-of-attack terms, modified by Theodorsen's function which accounts for circulation delay
$C(k)$	is Theodorsen's function in terms of the reduced frequency $k = \omega_e c/2U$ given as

$$C(k) = \frac{J_1(J_1 + Y_0) + Y_1(Y_1 - J_0) - i\,(Y_1 Y_0 + J_1 J_0)}{(J_1 + Y_0)^2 + (Y_1 - J_0)^2} \tag{14}$$

J_m and Y_m are Bessel functions of the first and second kind and m'th order. Due to the assumed negligible viscous forces, only the velocity normal to the foil element $\bar{V}_N$ need be considered. With $\bar{n}$ as the unit vector normal to the foil element and $\bar{v}_0$ as the velocity of the element

$$\bar{V}_N = (\bar{v}_0 \cdot \bar{n})\bar{n} \tag{15}$$

In a rotating coordinate system,

$$\bar{v}_0 = \bar{v} + (\bar{\Omega} \times \bar{r}) \tag{16}$$

where $\bar{v}$ is the velocity of the body coordinate's origin

$\bar{\Omega}$ is the angular rotational velocity of the moving system

$\bar{r}$ is the position vector of the foil element's midpoint X, Y, Z.

For small angles in pitch η_5 and yaw η_6

$$\bar{v} = -U\hat{i} + (\dot{\eta}_2 + U\eta_6)\hat{j} + (\dot{\eta}_3 - U\eta_5)\hat{k} \tag{17}$$

Substituting (17) into (16) and evaluating the cross-product term one obtains

$$v_o = \bar{i}\ (Z\dot{\eta}_5 - Y\dot{\eta}_6 - U)$$
$$+ \bar{j}\ (\dot{\eta}_2 + X\dot{\eta}_6 - Z\dot{\eta}_4 + U\eta_6)$$
$$+ \bar{k}\ (\dot{\eta}_3 + Y\dot{\eta}_4 - X\dot{\eta}_5 - U\eta_5) \qquad (18)$$

Upon substitution into equation (15)

$$\bar{V}_N = j\ [(\dot{\eta}_2 + X\dot{\eta}_6 - Z\dot{\eta}_4 + U\eta_6) \sin^2\Gamma$$
$$-(\dot{\eta}_3 + Y\dot{\eta}_4 - X\dot{\eta}_5 - U\eta_5) \sin\Gamma \cos\Gamma\ ]$$
$$+ \bar{k}\ [-(\dot{\eta}_2 + X\dot{\eta}_6 - Z\dot{\eta}_4 + U\eta_6) \sin\Gamma \cos\Gamma$$
$$+(\dot{\eta}_3 + Y\dot{\eta}_4 - X\dot{\eta}_5 - U\eta_5) \cos^2\Gamma \qquad (19)$$

where Γ is the dihedral angle of the foil element and $\bar{i}$, $\bar{j}$, $\bar{k}$ are unit vectors in the moving system's, x, y, z coordinate axes.

The derivative of $\bar{V}_N$ with respect to time neglecting nonlinear terms and cross terms gives

$$\bar{\dot{V}}_N = \bar{j}\ [(\ddot{\eta}_2 + X\ddot{\eta}_6 - Z\ddot{\eta}_4 + U\dot{\eta}_6) \sin^2\Gamma$$
$$- (\ddot{\eta}_3 + Y\ddot{\eta}_4 - X\ddot{\eta}_5 - U\dot{\eta}_5) \sin\Gamma \cos\Gamma\ ]$$
$$+ \bar{k}\ [-(\ddot{\eta}_2 + X\ddot{\eta}_6 - Z\ddot{\eta}_4 + U\dot{\eta}_6) \sin\Gamma \cos\Gamma$$
$$+(\ddot{\eta}_3 + Y\ddot{\eta}_4 - X\ddot{\eta}_5 - U\dot{\eta}_5) \cos^2\Gamma\ ] \qquad (20)$$

Substituting $\bar{V}_N$ and $\ddot{\bar{V}}_N$ into equations (11) thru (13), one obtains the three lift components in the translational displacements of surge, sway, and heave as:

Surge $\quad L_x = 0 \qquad (21)$

Sway
$$L_y = A(C_1 \sin^2\Gamma - C_2 \sin\Gamma \cos\Gamma) + B(C_3 \sin^2\Gamma - C_4 \sin\Gamma \cos\Gamma) - \frac{\partial L}{\partial h} C(k) \sin\Gamma \left[\eta_3 + Y\eta_4 - (X - \frac{c}{4})\eta_5\right] \qquad (22)$$

Heave
$$L_z = A(C_1 \sin\Gamma \cos\Gamma - C_2 \cos^2\Gamma) + B(C_3 \sin\Gamma \cos\Gamma + C_4 \cos^2\Gamma) + \frac{\partial L}{\partial h} C(k) \cos\Gamma \left[\eta_3 + Y\eta_4 - (X - \frac{c}{4})\eta_5\right] \qquad (23)$$

where
$$A = 0.25\,\pi\rho c^2 b$$
$$B = 0.50\rho UbcC_{L\alpha}C(k)$$
$$C_1 = \ddot{\eta}_2 + X\ddot{\eta}_6 - Z\ddot{\eta}_4 + U\dot{\eta}_6$$
$$C_2 = \ddot{\eta}_3 + Y\ddot{\eta}_4 - X\ddot{\eta}_5 - U\dot{\eta}_5$$
$$C_3 = \dot{\eta}_2 + (X + \frac{c}{4})\dot{\eta}_6 - Z\dot{\eta}_4 + U\eta_6$$
$$C_4 = \dot{\eta}_3 + Y\dot{\eta}_4 - (X + \frac{c}{4})\dot{\eta}_5 - U\eta_5$$

The third terms in the sway and heave equations (22 and 23) comprise a correction to the foil element's normal force; a modification due to the finite depth h.

The general moment equation, $\bar{M}$, for the three angular displacements is

$$\bar{M} = (\bar{L} \times \bar{r}) + \bar{M}' \qquad (24)$$

where the first term is the moment due to the lift force and the second term is the pure couple about the rotational axis passing through the foil's midpoint. The moments in roll, pitch and yaw can be expressed as follows with reference to equations (22) thru (24):

Roll $$M_\phi = L_y Z - L_z Y + M'_\phi \qquad (25)$$

Pitch $$M_\theta = L_z X + M'_\theta \qquad (26)$$

Yaw $$M_\psi = L_y X + M'_\psi \qquad (27)$$

The terms M'_ϕ , M'_θ , and M'_ψ are comprised of hydrodynamic moments of interia and damping.

$$M'_\phi = \frac{b^2}{12} (A\ddot{\eta}_4 + B\dot{\eta}_4 \qquad (28)$$

$$M'_\theta = \frac{1}{4} Ac \cos^2\Gamma(\frac{c}{8} \ddot{\eta}_5 + U\dot{\eta}_5) \qquad (29)$$

$$M'_\psi = \frac{1}{4} Ac \sin^2\Gamma(\frac{c}{8} \ddot{\eta}_6 + U\dot{\eta}_6) \qquad (30)$$

With foil symmetry about the xz-plane as a requirement, one can greatly simplify the foil portion of the coefficients whereby the six coupled equations of motion again are separable into two sets of coupled equations,i.e. (1) surge, heave, and pitch and (2) sway, roll, and yaw. The foil contribution to the coefficients of the two sets of coupled, second order differential equations (4) thru (6) and (7) thru (9) can

now be determined from L_x. L_y, L_z, M_ϕ, M_θ, and M_ψ. In calculating the foil coefficients a summation of all the rectangular foil element contributions on one side of the xz-plane is made and doubled due to symmetry. Tc this is added the contribution of the foil elements that lie in the xz-plane. Appendix A gives the foil coefficients for the symmetrical foil elements. The foil coefficients for the special case of an element lying in the xz-plane are approximated by taking half the values obtained in Appendix A.

Excitation Forces and Moments on the Hydrofoil

Consider now the wave excitation forces and moments acting on a hydrofoil element. For a foil element with an infinitesimal span, the lift acting through its midpoint located at a distance r from the orgin is

$$l = \pi\rho c U W_0 \{[J_0(K_1) - iJ_1(K_1)]\, C(k) + i\,\frac{k}{2}\,[J_0(K_1) + J_2(K_1)]\} \qquad (31)$$

where

$K_1 = \pi c \cos\mu/\lambda$; μ is heading angle

$K_2 = \omega^2/g$ the wave number, and

the term in parenthesis is Sear's function. W_0 is the orbital wave velocity component normal to the foil given by the expression

$$W_0 = i\zeta_a\omega(\cos\Gamma + i\sin\Gamma\sin\mu)\exp\{K_2[Z - i\,(X\cos\mu + Y\sin\mu)] + i\omega_e t\} \qquad (32)$$

with ζ_a as the wave amplitude.

Integration of l over the span with respect to the distance r gives the total excitation lift force, L, on the foil element at its midpoint

$$L = \pi\rho c U w_1 \{[J_0(K_1) - iJ_1(K_1)]\, C(k) + i\, 0.5k\, [J_0(K_1) + J_2(K_1)]\} \qquad (33)$$

where

$$w_1 = - i\zeta_a \left[\frac{2}{a} \sinh \left(\frac{ab}{2}\right)\right] [\cos\Gamma + i \sin\Gamma \sin\mu]$$
$$\exp \{K_2[Z - i\,(X \cos\mu + Y \sin\mu)] + i\omega_e t\}$$

and

$$a = K_2(\sin\Gamma - i \sin\mu \cos\Gamma)$$

The excitation forces for the three translational displacements can now be determined

Surge	$F_1' = 0$	(34)
Sway	$F_2' = - L \sin\Gamma$	(35)
Heave	$F_3' = L \cos\Gamma$	(36)

The moment excitation in roll is expressed by the equation

$$F_4' = \int l r dr + F_3' Y - F_2' Z \qquad (37)$$

where the integral is again over the foil element's span. With the appropriate integration

Roll
$$F_4' = \pi\rho c U w_2 \{[J_0(K_1) - iJ_1(K_1)]\, C(k) + i\, 0.5k\, [J_0(K_1) + J_2(K_1)]\} + F_3' Y - F_2' Z \qquad (38)$$

where

$$w_2 = - ih\omega \left[\frac{b}{a} \cosh \left(\frac{ab}{2}\right) - \frac{2}{a^2} \sinh \left(\frac{ab}{2}\right)\right]$$

$$[\cos\Gamma + i \sin\Gamma \sin\mu] \exp \{K_2[Z - i (X \cos\mu + Y \sin\mu)] + i\omega_e t \}$$

The two excitation moments in pitch and yaw are respectively

$$F_5 = (XL + M_{c/2}) \cos\Gamma \qquad (39)$$

$$F_6 = (XL + M_{c/2}) \sin\Gamma \qquad (40)$$

where $M_{c/2}$, the moment about mid-chord, is given as

$$M_{c/2} = 0.25 \pi\rho c^2 U w_1 \{J_0(K_1)C(k) + iJ_1(K_1) [1 - C(k)] - 0.25k [J_1(K_1) + J_3(K_1)] + J_2(K_1)\}$$

Since the excitation forces in sway, roll and yaw in head and following waves are negligible F_2', F_4', and F_6' are equated to zero in the computer program for headings within 8 degrees of μ = 180 or 0 degrees.

The summation of the excitation forces and moments on each foil element F_j' results in the total excitation forces and momets on the hydrofoil system $F_j e^{-i\omega_e t}$. For computational purposes, a second set of forcing functions was generated to be used on foil elements that are symmetrical about the xz-plane.

COMPUTER PROGRAM

Based on the foregoing mathematical model, a program was developed to compute the hullborne motions of a hydrofoil craft in regular waves of arbitrary heading. The program is essentially a modification of the already existing DTNSRDC Ship-Motion Computer Program. In itself the existing program can determine the hydrofoil craft's motions in the foil up mode in 6DOF in regular unidirectional waves of any heading. The modification consists of adding the foil system's coefficients of motion and its excitation forces and moments to the corresponding terms for the hull. As a consequence three card sets listed below and pertaining to the foil system of the hullborne hydrofoil craft are added onto the existing 34 data card sets, which are listed in Appendix B.

A. Input Description

Data Card Set 35 - one card with format (2I4)

IFOIL: 2 for hydrofoil craft in the foils down mode. All other integer values are for retracted foil systems where only the hull is subjected to hydrodynamics forces

IPRINT: option of printing the matrix equations of motion. With IPRINT = 0 printing of matricies is suppressed and for IPRINT = 1 printing of matricies takes place

Data Card Set 36 - One card with format (I5,3F12.2)

NF: total number of foil elements on the starboard side of the hydrofoil craft. This total consists of the elements in symmetry about the xz-plane plus the elements lying in the xz-plane

FVOL: is the displaced volume of the entire foil system (including the portion of the struts that are immersed). The units

is WORD**3, (see Data Card Set 4 of Reference 3 or Appendix C)

FXCB: the foil system's longitudinal center of buoyancy, LCB, with respect to the entire craft's LCB, i.e. the x value in the body coordinate system in units of WORD.

FZCB: the foil system's vertical center of buoyancy, VCB, i.e. the z value in the body coordinate system in units of WORD.

Data Card Set 37 - one card per foil element with format (F3.0, 5F7.2, F5.0, F10.7, F5.1, F8.3)

CPL: If the plane foil element lies in the center plane, i.e. the xz-plane,

CPL = 1.. In all other cases,

CPL = 2. due to the required symmetry of these elements about the center plane.

SPAN: the length of the rectangular foil element taken in a line parallel to the yz-plane in units of WORD.

CHORD: the width of the rectangular foil element taken in a line parallel to the xz-plane in units of WORD.

S: x coordinate of the foil element's midpoint in units of WORD

YF: y coordinate of the foil element's midpoint in units of WORD

ZF: z coordinate of the foil element's midpoint in units of WORD

DGAMMA: is the dihedral angle, i.e. the angle between the starboard plane foil element and the horizontal xy-plane in degrees, see Figure 3

CLZ: is the vertical lift slope of the foil element in dimensionless units

ASP: is a positive number utilized in the aspect ratio correction factor AR/(AR + ASP) for foil elements of finite span. For the example cited AR = 0.

Provided that the hydrofoil system can be represented by a set of rectangular foil elements symmetrical about the center plane, each foil element fits into one of three categories as:

1. The most commonly encountered foil element not lying in the center plane counts as one element with CPL = 2.

2. The special case of a foil element lying in the center plane counts as one element with CPL = 1, and a dihedral angle of 90 degrees.

3. The special case of a foil element with a dihedral angle of 0 degrees intersecting the center plane is considered as just that portion of the foil lying on the starboard side from the center plane. The span is then just the distance from the center plane to the foil tip, and the midpoint YF = SPAN/2, and CPL = 2.

The listing of the Hullborne Hydrofoil Six-Degree of Freedom Motion Computer Program is given in Appendix C. The original program's organization consisted of a main program and a series of thirty subprograms. These routines are divided into four overlays and all are written in FORTRAN IV. Currently, the program is used on DTNSRDC's CDC 6700 computer system. Updated is the main program HANSEL in the main overlay, and the subroutines PRGM1 in the first overlay, and SPRG5 in the third overlay, see Reference 3. To this is added the subroutine FOIL which computes the foil coefficients of motion and the excitation forces and moments and three

additional subroutines THEO, EXCIT, and IBESJ which are required for calculations in FOIL. The final organization of the Hullborne Hydrofoil Six-Degree of Freedom Computer Program is presented in Figure 4.

COMPARISON OF PREDICTED AND EXPERIMENTAL RESULTS

The experimental results chosen for comparison with predicted results were the hullborne motion measurements of a model of the 313-ton Plainview AG(EH)-1 hydrofoil craft as presented in Reference 6. The experiments were conducted on a 1:12 scale model in DTNSRDC's Harold E. Saunders Seakeeping and Maneuvering Facility. The model was run in both the foils up and foils down modes in unidirectional regular waves. The full scale velocities were 6 and 12 knots at the three headings of head (180^0), bow (150^0), and beam waves (90^0). The regular waves were of a constant wave steepness 1/60 and wave lengths ranged from $\lambda/L = 0.25$ to $\lambda/L = 3.0$, corresponding to wave frequencies of $\omega = 0.57$ to 1.98 rad/sec.

The Hullborne Hydrofoil Six-Degree of Freedom Motion Program was likewise run in both the foils up and foils down modes at the three headings of 180^0, 150^0, and 90^0. The predicted motions generally agreed well with the experimental results as shown in Figures 5 through 11, which show the craft's transfer function versus wave encounter frequency together with the phase lag with respect to the maximum height of the wave at the CG. At the headings of 90 and 150 degrees, both the theoretical and experimental results show that the immersion of the foils significantly reduces the craft's motion in roll. The foil system's effects in reducing pitch and heave are much less pronounced.

Some of the minor discrepancies, especially in roll, between the predicted and experimental results are likely attributable to differences in the roll gyradii of the physical and simulation models since they were not given for the model for either the foil up or the foil down mode. A less significant source

for error may also be inaccuracies in the estimation of the foil system's displacement and center of buoyancy.

CONCLUDING REMARKS

The motions predicted for the AG(EH)-1 hydrofoil craft in the hullborne condition using the DTNSRDC Hullborne Hydrofoil 6DOF Computer Program agree satisfactorily with the available experimental data, namely for the heading angles of 90, 150, and 180 degrees.

Additional comparisons directed toward verification of the DTNSRDC Hullborne Hydrofoil 6-D Motion Computer Program should be made as more experimental results are made available. The program in its present state cannot be used to predict motions at zero craft speed and in conditions of negative encounter frequencies.

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2. Schmitke, R.T., "Computer Programs for Predicting the Pitch and Heave Motions of Hullborne Hydrofoil Vessels", Defense Research Establishment Atlantic, Darmouth, Nova Scotia; Jan 1974

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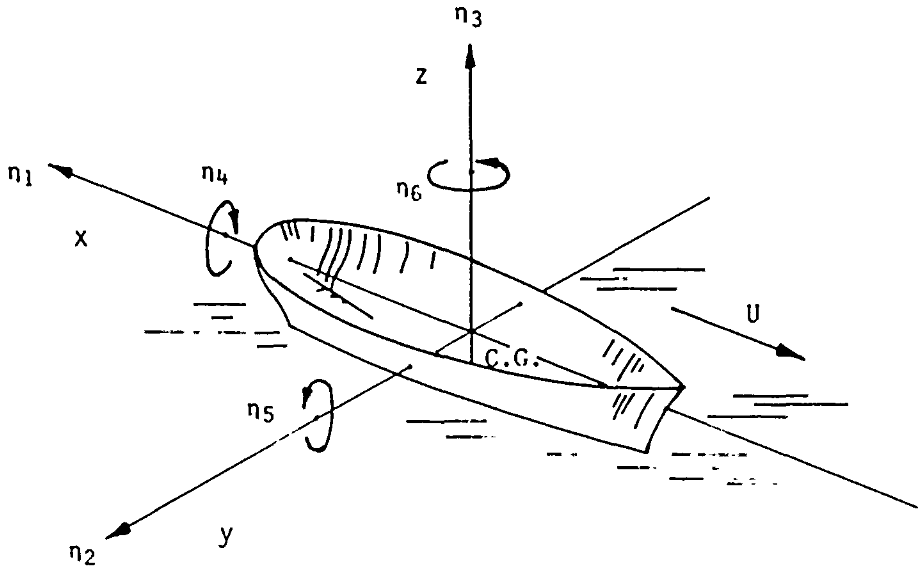
5. Bisplinghoff, R.L., Ashley, H. and Halfman, R.L. "Aeroelasticity" Addison-Wesley; Reading, Massachusetts, 1955

6. Vuolo, R.M., "A Study of the AGEH Hydrofoil Boat in the Displacement Mode (U)," Naval Ship R&D Center Report No. HMLC332-H-01, June 1969



TRANSLATORY DISPLACEMENTS	η_1 = SURGE
	η_2 = SWAY
	η_3 = HEAVE
ANGULAR DISPLACEMENTS	η_4 = ROLL
	η_5 = PITCH
	η_6 = YAW

Figure 1 - Sign Convention of Coordinate System with Origin at the C.G.

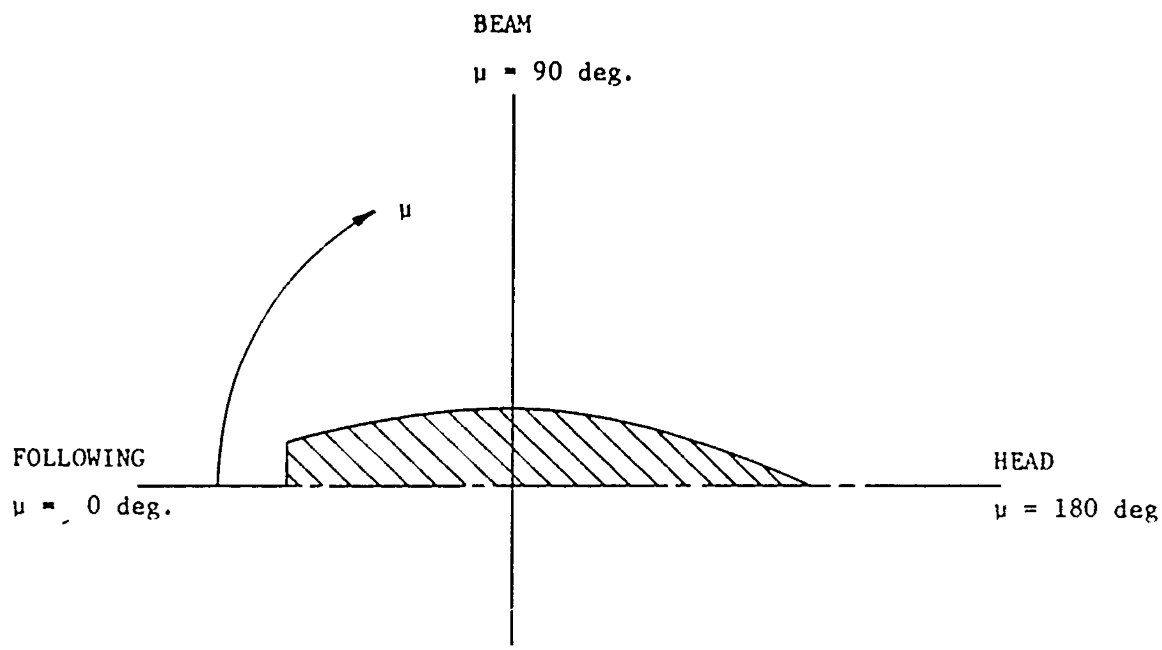


Figure 2 - Definition of Heading Angle, μ

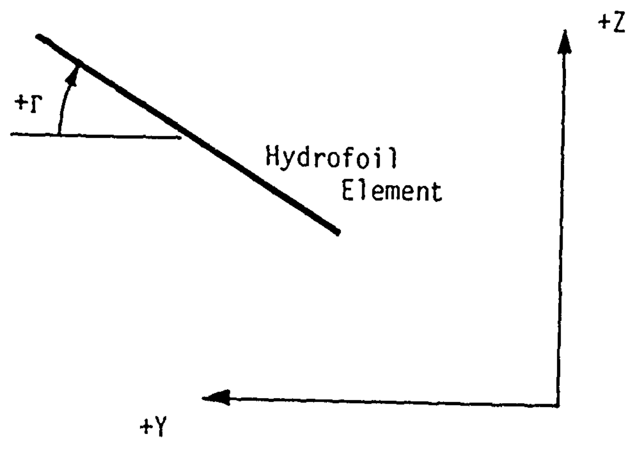


Figure 3 - Definition of Hydrofoil Element Angle, Γ

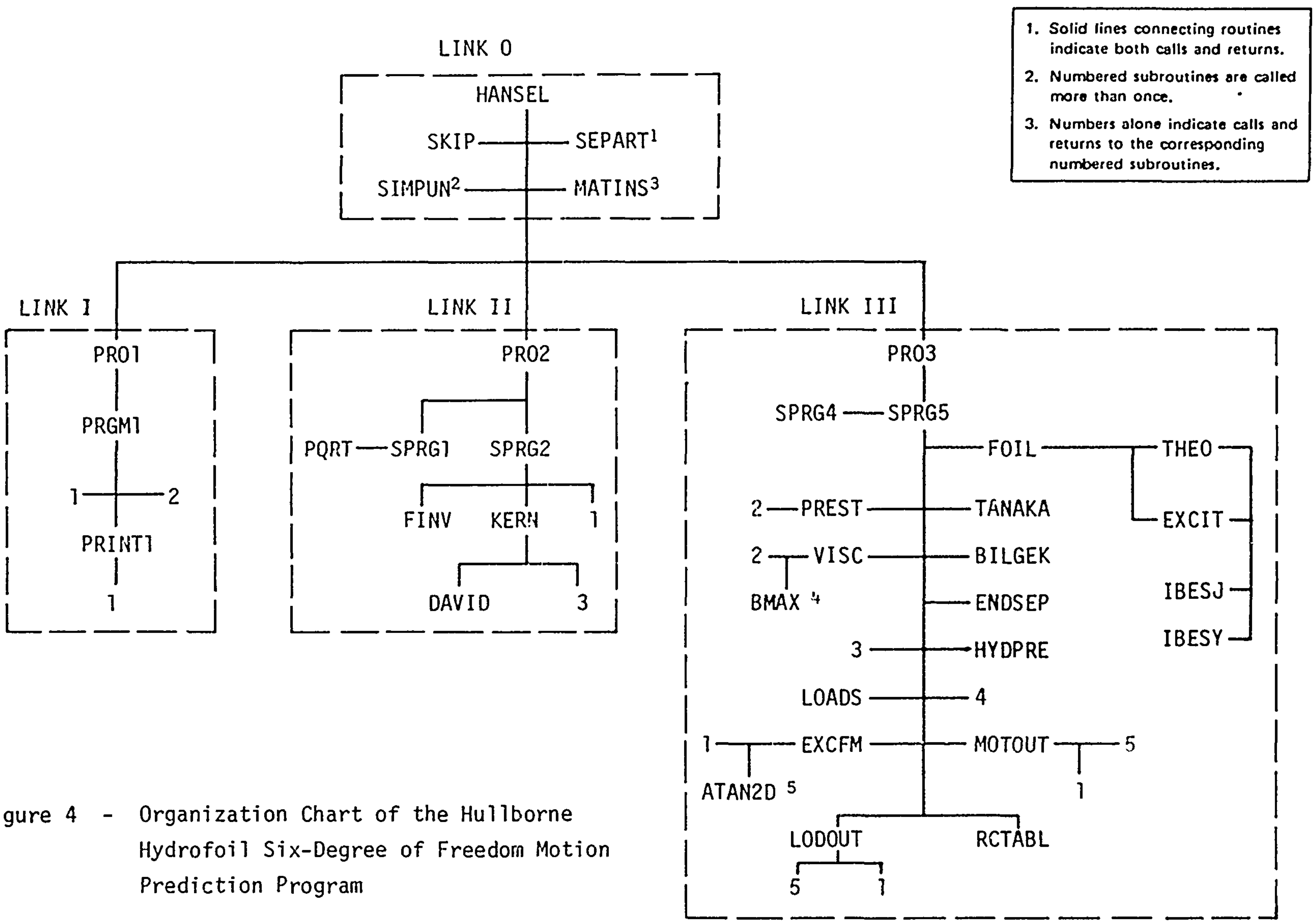


Figure 4 - Organization Chart of the Hullborne Hydrofoil Six-Degree of Freedom Motion Prediction Program

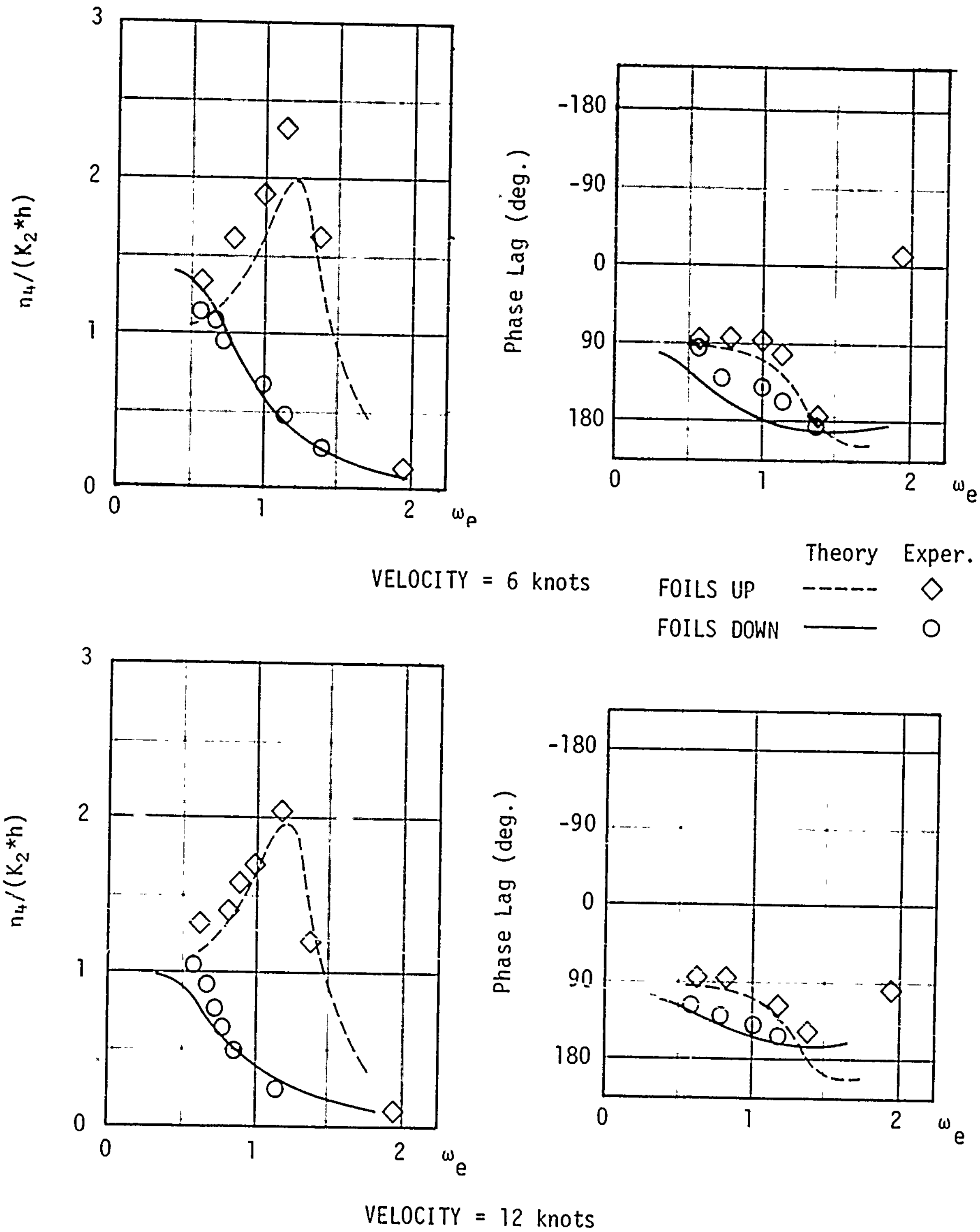


Figure 5 - Non-Dimensional Transfer Function and Phase Versus Wave Frequency of Encounter for Beam Sea Roll

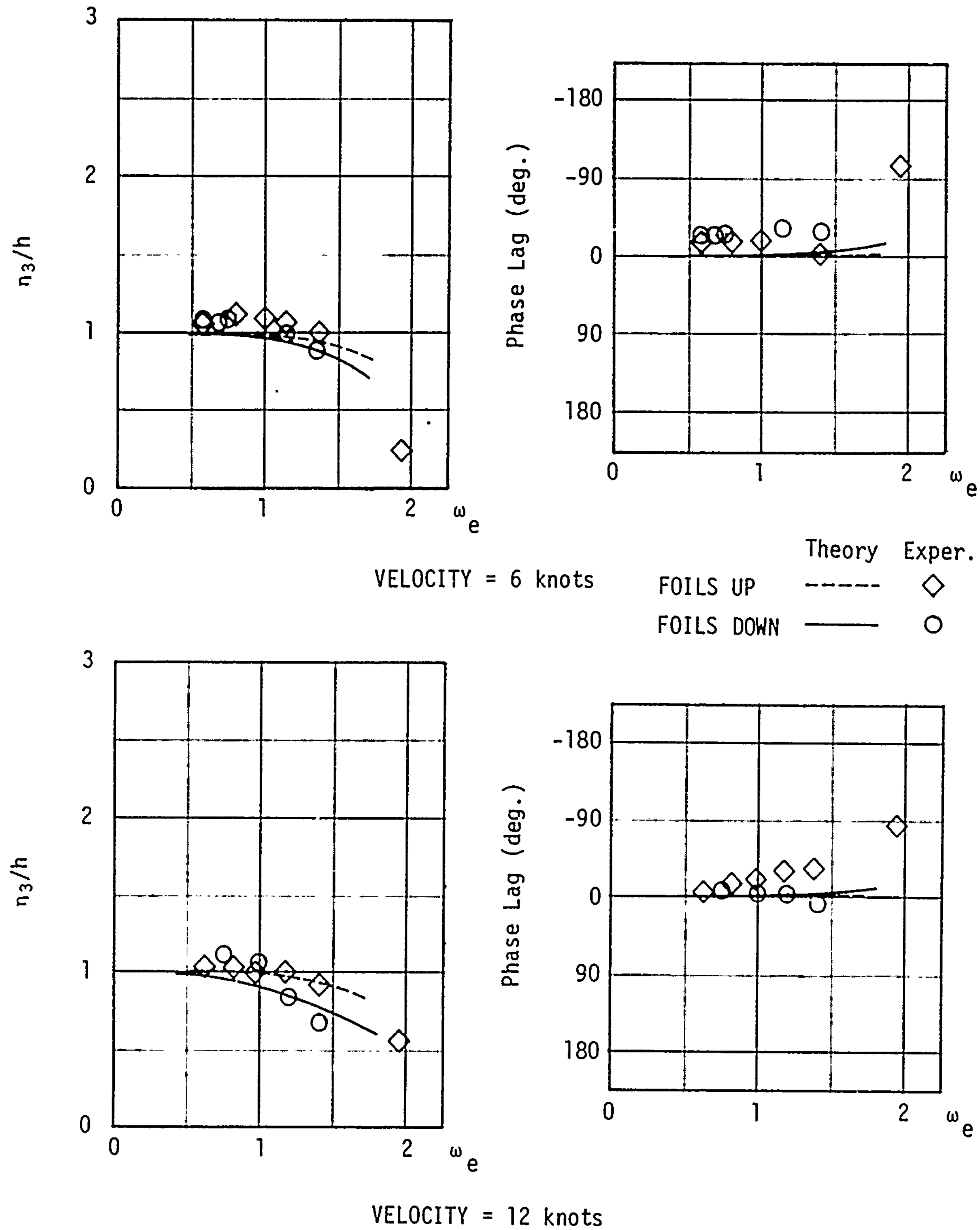


Figure 6 - Non-Dimensional Transfer Function and Phase Versus Wave Frequency of Encounter for Beam Sea Heave

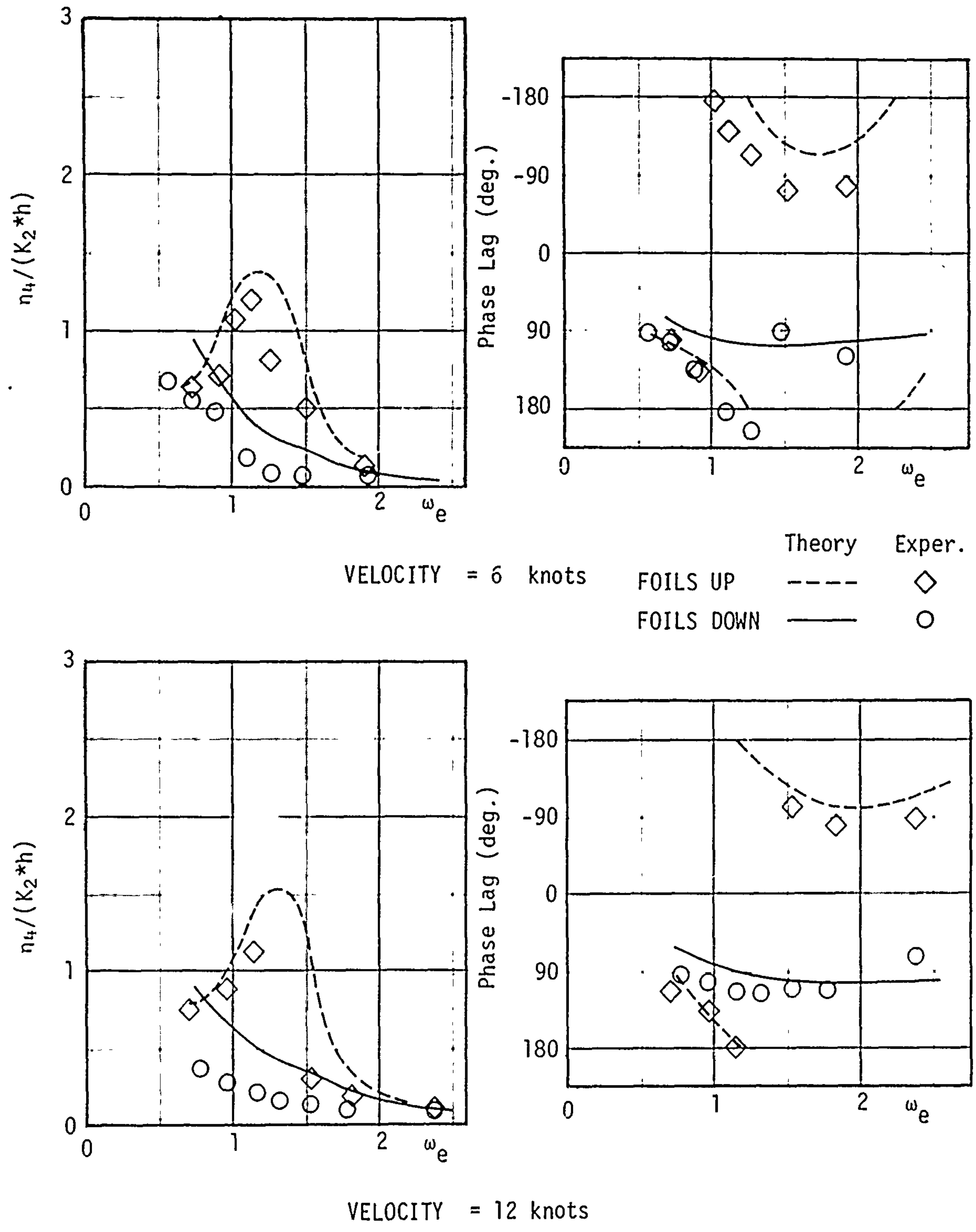


Figure 7 - Non-Dimensional Transfer Function and Phase Versus Wave Frequency of Encounter for Bow Sea Roll

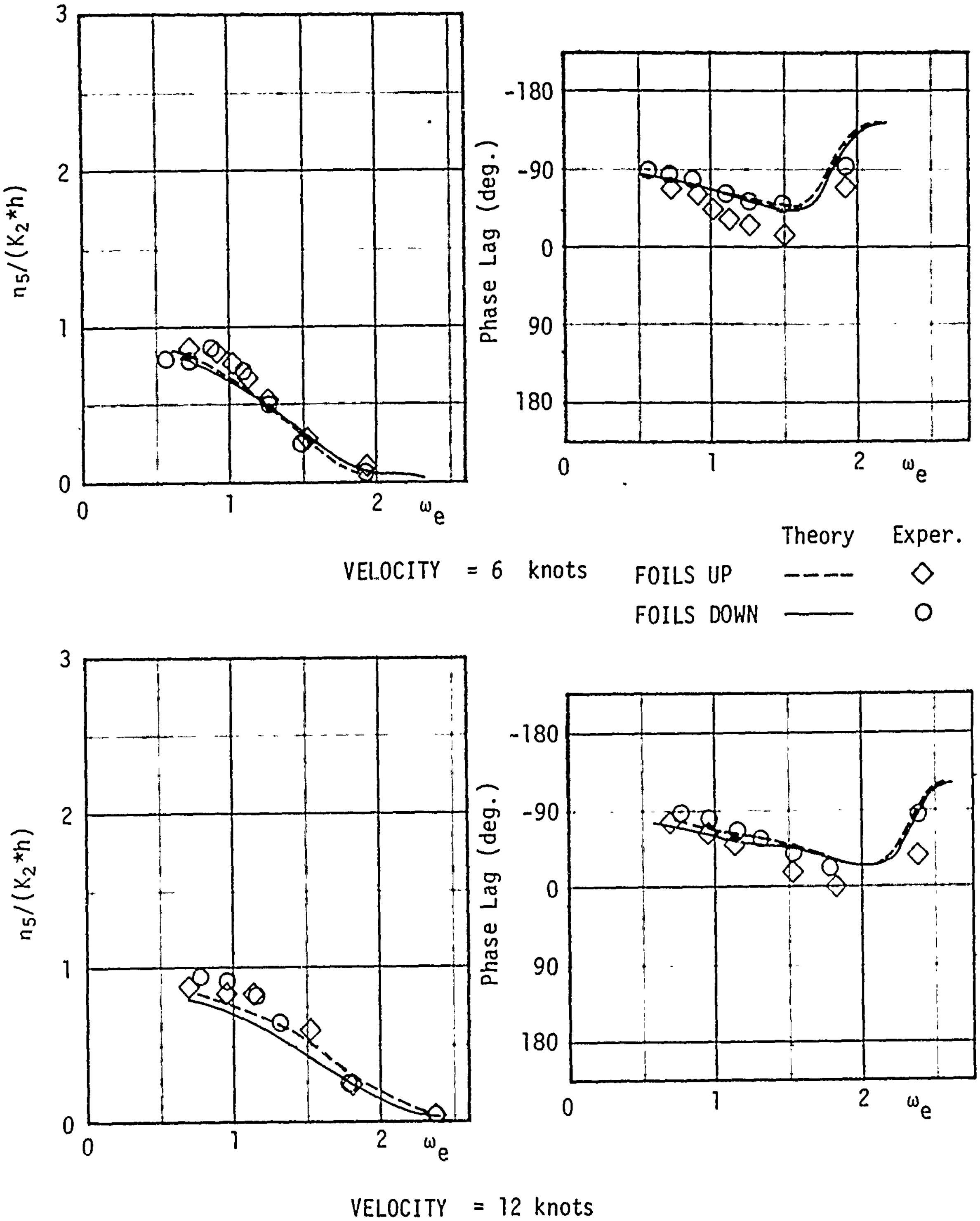


Figure 8 - Non-Dimensional Transfer Function and Phase Versus Wave Frequency of Encounter for Bow Sea Pitch

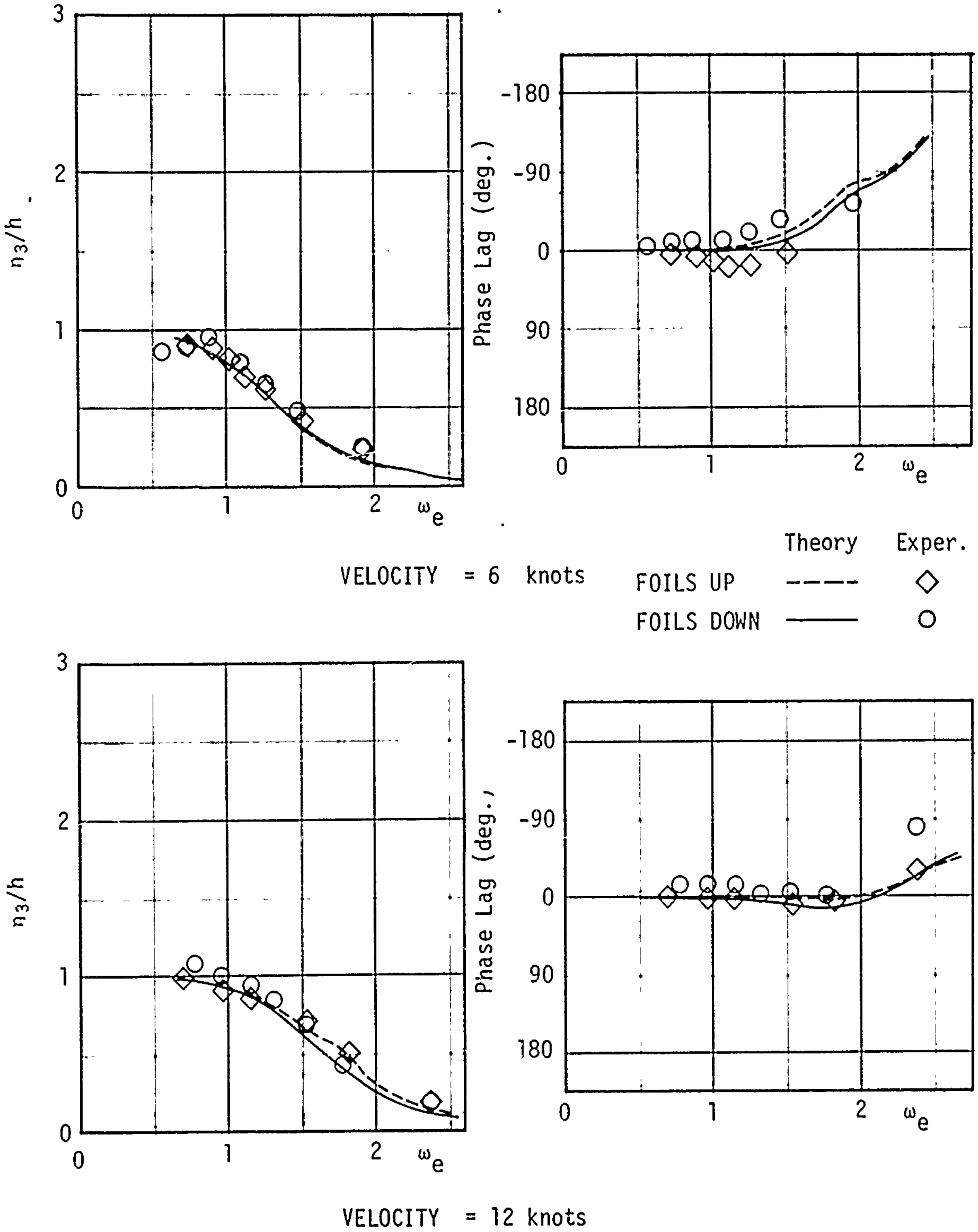


Figure 9 - Non-Dimensional Transfer Function and Phase Versus Wave Frequency of Encounter for Bow Sea Heave

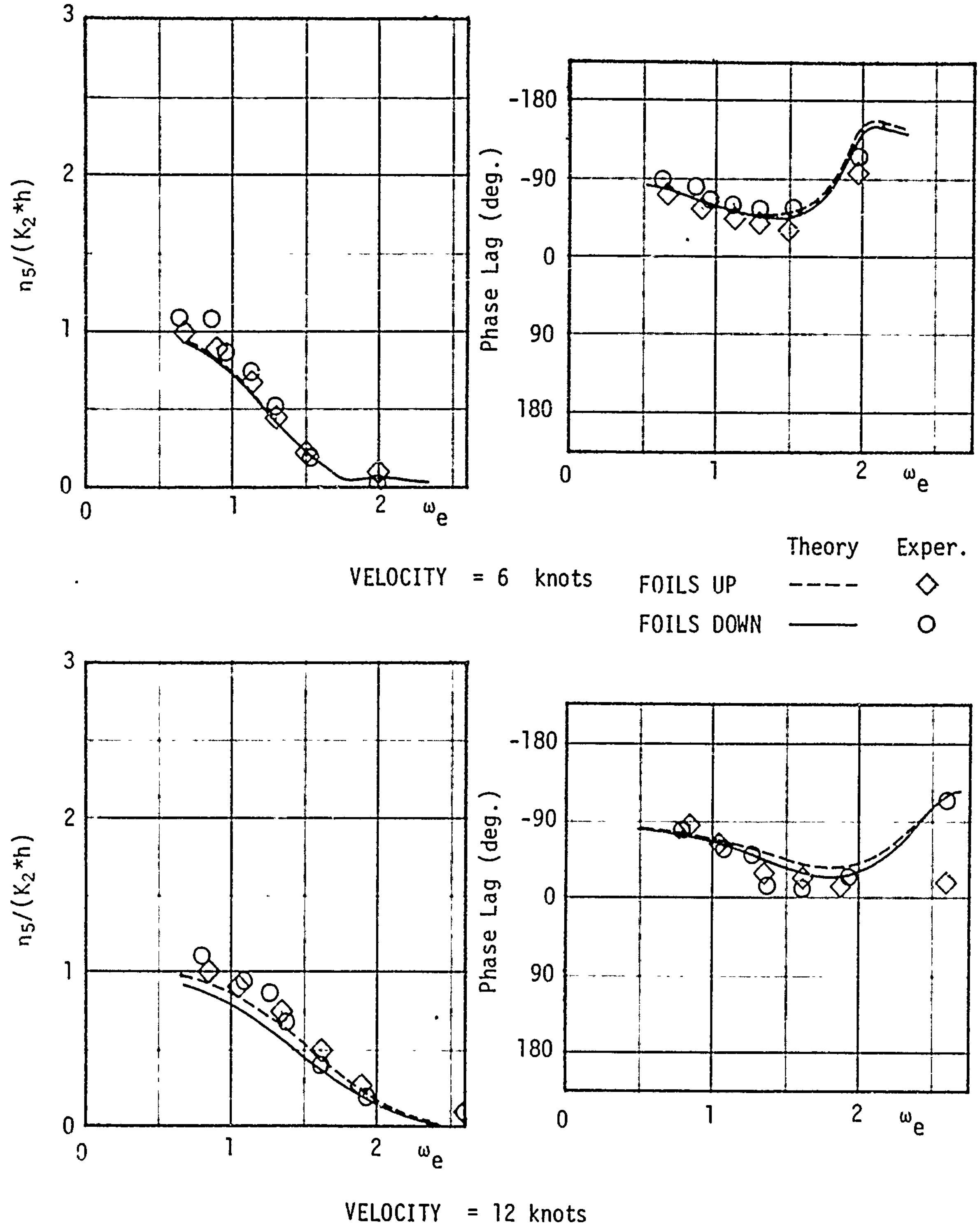


Figure 10 - Non-Dimensional Transfer Function and Phase Versus Wave Frequency of Encounter for Head Sea Pitch

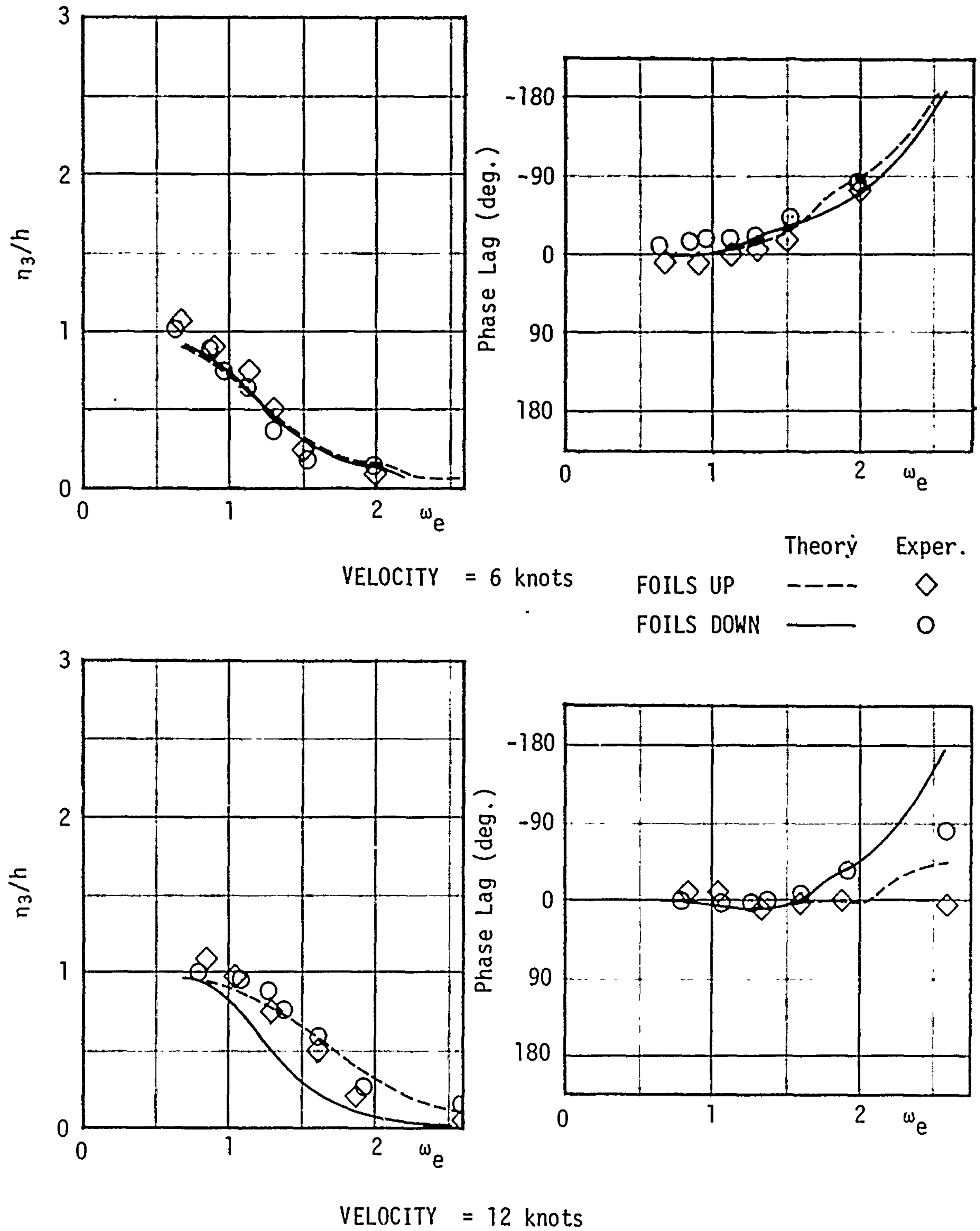


Figure 11 - Non-Dimensional Transfer Function and Phase Versus Wave Frequency of Encounter for Head Sea Heave

APPENDIX A

LISTING OF HYDROFOIL COEFFICIENTS

The hydrofoil portion of the added mass, damping, and restoring coefficients of the two sets of three simultaneous differential equations of motions in (1) surge, heave, and pitch and in (2) sway, roll, and yaw are listed below for retangular foil elements in symmetry about the xz-plane. For the special case of a foil element lying in the xz-plane, half of the magnitudes given below give a good approximation. The coefficients are in:

Surge: $A^F_{1j} = B^F_{1j} = C^F_{1j} = 0 \; ; \; j = 1, 3, 5$

Heave: $A^F_{31} = B^F_{31} = C^F_{31} = 0$

$$A^F_{33} = \frac{1}{2}\pi \rho \Sigma \; bc^2 \cos^2 \Gamma$$

$$B^F_{33} = \rho U \; \Sigma \; bcC_{L\alpha} C(k) \cos^2 \Gamma$$

$$C^F_{33} = 2 \; \Sigma \; \frac{\partial L}{\partial h} C(k) \cos \Gamma$$

$$A^F_{35} = -\frac{1}{2} \pi \rho \; \Sigma \; bc^2 X \cos^2 \Gamma$$

$$B^F_{35} = -\frac{1}{2} \pi \rho U \Sigma bc^2 X \cos^2 \Gamma$$

$$- \rho U \Sigma bcC_{L\alpha} C(k)(X + \frac{c}{4}) \cos^2 \Gamma$$

$$C^F_{35} = -\rho U^2 \Sigma bcC_{L\alpha} C(k) \cos^2 \Gamma$$

$$+ 2\Sigma \frac{\partial L}{\partial h} C(k)(X - \frac{c}{4}) \cos \Gamma$$

Sway: $A^F_{22} = \frac{1}{2}\pi\rho\Sigma bc^2\sin^2\Gamma$

$$B^F_{22} = \rho U\Sigma bcC_{L\alpha}C(k)\sin^2\Gamma$$

$$A^F_{24} = -\frac{1}{2}\pi\rho\Sigma bc^2\sin\Gamma(Z\sin\Gamma + Y\cos\Gamma)$$

$$B^F_{24} = -\rho U\Sigma bcC_{L\alpha}C(k)\sin\Gamma(Z\sin\Gamma + Y\cos\Gamma)$$

$$C^F_{24} = -2\Sigma\frac{\partial L}{\partial h}C(k)\,Y\sin\Gamma$$

$$A^F_{26} = \frac{1}{2}\pi\rho\Sigma\,bc^2X\sin^2\Gamma$$

$$B^F_{26} = \frac{1}{2}\pi\rho U\Sigma bc^2\sin^2\Gamma$$

$$+\ \rho U\Sigma bcC_{L\alpha}C(k)(X + \frac{c}{4})\sin^2\Gamma$$

$$C^F_{26} = \rho U^2\Sigma bcC_{L\alpha}C(k)\sin^2\Gamma$$

Roll: $A^F_{42} = -\frac{1}{2}\pi\rho\Sigma bc^2\sin\Gamma(Z\sin\Gamma + Y\cos\Gamma)$

$$B^F_{42} = -\rho U\Sigma bcC_{L\alpha}C(k)\sin\Gamma(Z\sin\Gamma + Y\cos\Gamma)$$

$$A^F_{44} = \frac{1}{24}\pi\rho\Sigma b^3c^2 + \frac{1}{2}\pi\rho\Sigma bc^2(Z\sin\Gamma + Y\cos\Gamma)^2$$

$$B_{44} = \frac{1}{12}\rho U\,\Sigma C_{L\alpha}C(k)\,b^3c + \rho U\Sigma bcC_{L\alpha}C(k)(Z\sin\Gamma + Y\cos\Gamma)^2$$

$$C^F_{44} = 2\Sigma\frac{\partial L}{\partial h}C(k)Y(Y\cos\Gamma + Z\sin\Gamma)$$

$$A^F_{46} = -\frac{1}{2}\tau\rho\Sigma bc^2X\sin\Gamma(Z\sin\Gamma + Y\cos\Gamma)$$

$$B^F_{46} = -\frac{1}{2}\pi\rho U\Sigma bc^2\sin\Gamma(Z\sin\Gamma + Y\cos\Gamma)$$

$$-\ \rho U\Sigma bcC_{L\alpha}C9k)(X + \frac{c}{4})\sin\Gamma(X\sin\Gamma + Y\cos\Gamma)$$

$$C^F_{46} = -\rho U^2\Sigma bcC_{L\alpha}C(k)\sin\Gamma(Z\sin\Gamma + Y\cos\Gamma)$$

Pitch: $A^F_{51} = B^F_{51} = 0$

$$A^F_{53} = -\frac{1}{2}\pi\rho\Sigma bc^2 X\cos^2\Gamma$$

$$B^F_{53} = -\rho U\Sigma bcC_{L\alpha}C(k)(X - \frac{c}{4})\cos^2\Gamma$$

$$C^F_{53} = -2\Sigma\frac{\partial L}{\partial h}C(k)(X-\frac{c}{4})\cos\Gamma$$

$$A_{55} = \frac{1}{64}\pi\rho\Sigma bc^4\cos^2\Gamma + \frac{1}{2}\pi\rho\Sigma bc^2X^2\cos^2\Gamma$$

$$B_{55} = \frac{1}{2}\pi\rho U\Sigma bc^2X\cos^2\Gamma + \frac{1}{8}\pi\rho U\Sigma bc^3\cos^2\Gamma$$
$$+ \rho U\Sigma bcC_{L\alpha}C(k)(X + \frac{c}{4})(X - \frac{c}{4})\cos^2\Gamma$$

$$C_{55} = \rho U^2\Sigma bcC_{L\alpha}C(k)(X - \frac{c}{4})\cos^2\Gamma$$
$$+ 2\Sigma\frac{\partial L}{\partial h}C(k)(X + \frac{c}{4})(X - \frac{c}{4})\cos\Gamma$$

Yaw: $A_{62} = \frac{1}{2}\pi\rho\Sigma bc^2X\sin^2\Gamma$

$$B_{62} = \rho U\Sigma bcC_{L\alpha}C(k)(X - \frac{c}{4})\sin^2\Gamma$$

$$A_{64} = -\frac{1}{2}\pi\rho\Sigma bc^2X\sin\Gamma(Z\sin\Gamma + Y\cos\Gamma)$$

$$B_{64} = -\rho U\Sigma bcC_{L\alpha}C(k)(X - \frac{c}{4})\sin\Gamma(Z\sin\Gamma + Y\cos\Gamma)$$

$$C_{64} = -2\Sigma\frac{\partial L}{\partial h}C(k)(X - \frac{c}{4})Y\sin\Gamma$$

$$A_{66} = \frac{1}{64}\pi\rho\Sigma bc^4\sin^2\Gamma + \frac{1}{2}\pi\rho\Sigma bc^2X^2\sin^2\Gamma$$

$$B_{66} = \frac{1}{2}\pi\rho U\Sigma bc^2X\sin^2\Gamma + \rho U\Sigma bcC_{L\alpha}C(k)(s + \frac{c}{4})(s - \frac{c}{4})\sin^2\Gamma$$
$$+ \frac{1}{8}\pi\rho U\Sigma bc^3\sin^2\Gamma$$

$$C_{66} = \rho U^2\Sigma bcC_{L\alpha}C(k)(X - \frac{c}{4})\sin^2\Gamma$$

The lift slope curve, $C_{L\alpha}$, is taken in the program as equal to 2π

APPENDIX B

DATA CARD FORMAT DESCRIPTION OF NSRDC SHIP-MOTION COMPUTER PROGRAM AS PERTAINING TO THE HULLBORNE HYDROFOIL CRAFT MOTION COMPUTER PROGRAM (Data Card Sets 1 - 34)

For a particular hullborne hydrofoil craft the input on punched cards consists of 37 Data Card Sets. A description of the initial 34 non-hydrofoil related Data Card Sets (see Reference 2) is given below. Deleted are those sets that deal with the Sea-Load portion of the original Computer Program. The exact number of Data Card Sets as well as the number of cards in each set will vary according to the requirements of a particular problem. The final Data Card Sets 35, 36, and 37 which relate to the hydrofoil system are described in the text.

Data Card Set 1, one card, FORMAT (3A10).

This card contains three alphanumeric variables used to identify the output.

(1) NAME1, columns 1 - 10, identifies the user's name.

(2) NAME2, columns 11 - 20, identifies the user's code,

(3) NAME3, columns 21 - 30, identifies the user's telephone extension.

Data Card Set 2, one card, FORMAT (5X, A4, 7X, A3, 8X, A3).

This card contains three alphanumeric variables used as controls for a number of options. The spelling of the values of the variables is tested in the program against defined names. Hence care should be exercised in using the correct spelling.

(1) IPASS, columns 6 - 9, is a control for reading in Data Card Sets 3 - 34. The options are,

IPASS = GOGO, read-in sets 3 - 34.

IPASS = STOP, program stops.

IPASS undefined, GOGO assumed (default).

(2) OTAPE, columns 17 - 19, is a control for positioning the output tape. Results are stored on an output tape as well as printed out. The options are:

OTAPE = NEW, no tape positioning, new tape.

OTAPE = OLD, output tape automatically positioned past previous results.

OTAPE undefined, NEW assumed (default).

(3) PRNTOP, columns 28 - 30, is a printout option.

PRNTOP = MAX, maximum printing.

PRNTOP = MIN, printing of results suppressed, only data cards listed.

PRNTOP undefined, MAX assumed (default).

NOTE - Data Card Set 2 provides a method for including data for more than one ship at a time. This set should be placed before and after the cards for each ship (Data Card Sets 3 - 34). After the data for the last ship use IPASS = STOP.

Data Card Set 3, one card, FORMAT (12A6).

This card contains alphanumeric information identifying the project, ship, calculations, etc.

TITO (array), columns 1 - 72.

Data Card Set 4, one card, FORMAT (2A6, A8)

This card contains three alphanumeric variables.

(1) WORD, columns 1 - 6, identifies the input length unit used. A unit commonly used is FEET. All dimensional variables input to the program must be in units consistent with this length unit.

(2) WORD2, columns 7 - 12, identifies the force unit, if WORD = FEET then WORD2 = TONS.

(3) WORD3, columns 13 - 20, identifies the moment unit. If WORD = FEET then WORD3 = FT-TONS.

WORD, WORD2, and WORD3 are printed out with the dimensional part of the output to identify the dimensional units.

Data Card Set 5, one card, FORMAT (4I6)

This card contains four integer variables.

(1) NUT $\leq$ 8, column 6, is the number of offset points used to describe each station. All stations must have the same number of offsets. It is recommended that 8 offset points be used.

(2) NST $\leq$ 27, columns 11 - 12, is the number of stations used to longitudinally subdivide the ship.

(3) NMAS = NST, columns 17 - 18, is the number of mass points. If IT $\neq$ 0 (see the next integer description) then punch a one in column 18.

(4) IT, column 24, is a control for reading in Data Card Set 9 or Data Card Sets 10 - 14.

IT = 0, read in the mass and mass-distribution data for each station, contained in Data Card Sets 10 - 14. This option must be used when load calculations are desired.

IT $\neq 0$, read in the mass and mass-distribution data for the ship as a whole, contained on Data Card Set 9. This option is used when only motion calculations are desired.

Data Card Set 6, from one to four cards. FORMAT (8F10.4)

This card set contains the NST station numbers, ST1(I), used to longitudinally subdivide the ship. The stations are input in the order they occur along the ship starting with the first station at the extreme forward point of the ship. For example, 0.0, 0.25, 1.0, • • •, 19.75, 20.0. See Appendix B.1 for recommended station numbering.

ST1 (array), columns 1 - 10, 11 - 20, • • •, 71 - 80/repeat for up to four cards, eight numbers per card.

Data Card Set 7, one card, FORMAT (2F10.4)

This card contains the following two floating point numbers:

(1) ELL, columns 1 - 10, is the length between perpendiculars, L_{pp}, in WORD units.

(2) BEAM, columns 11 - 20, is the beam at midships in WORD units.

Data Card Set 8, two cards for each of NST-2 stations, a total of 2 • (NST-2) cards, FORMAT (8F10.4)

This card set contains the y and z coordinates of the offset points for each of NST-2 stations (see Figures 4 and 5). The foremost and aftermost stations have no offsets and are not specified in this data card set. Appendix B.2 provides information on allowable section shapes and contour specifications.

(1) Y (array), first card, columns 1 - 10, 11 - 20, • • •, 71 - 80, contains the NUT y coordinates of the offset points for Section I* in WORD units. The y coordinates (positive) are given proceeding clockwise around the station contour, with the first y value at the intersection of the waterline and the station contour, and the last y value at the intersection of the centerline and the station contour. For fully submerged sections the first y value is zero.

(2) Z (array), second card, columns 1 - 10, 11 - 20, • • •, 71 - 80, contains the NUT z coordinates (negative) of the offset points for Section I in WORD units. The z coordinates are given in the same manner as the y coordinates. For fully submerged sections the first z value is at the intersection of the station contour nearest the free surface and the centerline.

Data Card Set 9, one card, FORMAT (F10.4, 4F10.6, F10.4)

This card set is included when motions only are desired. In this case, IT $\neq 0$ (see Data Card Set 5). This card set contains six floating point numbers.

(1) TMASS, columns 1 - 10, is the total mass of the ship in units consistent with the WORD length unit. For example, if FEET is the length unit, the mass unit would be TONS • SECONDS^2/FEET.

*Note that station number ST1(I+1) is associated with Section I.

(2) EI44, columns 11 - 20, is the square of the roll radius of gyration divided by the length between perpendiculars, $(K_\phi/L_{pp})^2$

(3) EI55, columns 21 - 30, is the square of the pitch radius of gyration divided by the length between perpendiculars, $(K_\theta/L_{pp})^2$

(4) EI66, columns 31 - 40, is the square of the yaw radius of gyration divided by the length between perpendiculars, $(K_\psi/L_{pp})^2$ Usually EI66 is set equal to EI55.

(5) EI46, columns 41 - 50, is the mass product of inertia about the x and z axes divided by TMASS $\cdot$ ELL.^{2} EI46 is very close to zero for most ships and in fact equal to zero for ship with fore and aft symmetry.

(6) ZG, columns 51 - 60, is the z coordinate of the center of gravity, CG, of the ship referenced to the waterline in WORD units (positive for CG above the waterline).

The next five Data Card Sets, 10 through 14, are included when load calculations are desired. In this case, IT = 0 (Data Card Set 5) and Data Card Set 9 is not required.

Data Card Sets 10-14 Delete

Data Card Set 15, one card, FORMAT(I6)

This card contains one integer variable.

IXAST, columns 5 - 6, is only used when end-effect corrections are made to the added-mass and damping coefficients for ships with transom type sterns (Data Card Set 23, IEND = 1). In this case, IXAST = NST - 2, which is the sequence number of the last section along the hull near the stern. Note that this card set must be included irrespective of the value of IEND.

Data Card Set 16, one card, FORMAT (4I6)

This card contains four integer variables.

(1) NOK $\leqslant$ 30, columns 5 - 6, is the number of wavelengths for which motion and load calculations are performed.

(2) NOB $\leqslant$ 5, column 12, is the number of Froude numbers for which motion and load calculations are performed.

(3) NOH $\leqslant$ 10, columns 17 - 18, is the number of headings for which motion and load calculations are performed.

(4) NWSTP $\leqslant$ 12, columns 23 - 24, is the number of waveslopes for which motion and load calculations are performed.

Data Card Set 17, one card, FOPMAT (1216)

This card contains the NWSTP reciprocals of wave steepness, INWSTP(I), defined as the ratio of wavelength to wave height, λ/ζ_W, i.e., 50, 80, 110. Wave slope in degrees is determined in the program as 180/INWSTP(I). The program also computes a wave amplitude for each wavelength as $\zeta_A = \lambda/[2 \cdot INWSTP(I)]$ where the wave slope is kept constant for each heading and Froude number. See Section IIA for a discussion of the use of wave amplitude in the nonlinear viscous roll-damping calculations and Section IV for a general discussion about the use of wave amplitude for scaling the output.

Data Card Set 18, from one to two cards, FORMAT (8F10.4)

This card set contains the NOH heading angles, HDG1(I), in degrees. The convention used in the program is head waves = 180 degrees.

Data Card Set 19, one card, FORMAT (5F10.4)

This card contains the NOB Froude numbers, FN(I). The Froude number is defined as,

$$F_n = \frac{V}{\sqrt{g \cdot L_{pp}}}$$

where V is the ship speed in feet/second, g is the acceleration due to gravity, and L_{pp} is the length between perpendiculars.

Data Card Set 20, from one to four cards, FORMAT (8F10.4)

This card set contains the NOK numbers of nondimensional wavelengths, BAM(I), for which calculations are to be performed. The wavelength is nondimensionalized by the length between perpendiculars, λ/L_{pp}.

Data Card Set 21, one card, FORMAT (I5, 2F10.4)

This card contains one integer variable and two floating point variables:

(1) NFR $\leqslant$ 40, columns 4-5, is the number of nondimensional frequencies of encounter, ω_{EN}, for which added-mass and damping values are calculated. The nondimensional frequency is defined by,

$$\omega_{EN} = \omega_E \cdot \sqrt{L_{pp}/g}$$

where ω_E is the dimensional frequency of encounter, L_{pp} is the length between perpendiculars, and g is the acceleration due to gravity. Note that NFR is in an I5 field instead of the usual I6. If NFR is undefined, the program will compute a value for it.

(2) OMIN, columns 6-15, defines the lower end of the range of ω_{EN} values. If OMIN is undefined, the program will compute a value.

(3) OMAX, columns 16-25, defines the higher end of the range of ω_{EN}. If OMAX is undefined, the program will compute a value.

Data Card Set 22, one card, FORMAT (I6)

This card contains one integer variable.

IRR, column 6, is a control for interpolating the added-mass and damping values if irregular frequencies exist.

IRR = 1, no irregular frequencies.

IRR = 2, irregular frequencies exist.

IRR undefined, program will supply the proper value.

See Appendix C for a discussion of the effect of irregular frequencies on the calculation of the range of nondimensional frequencies and on the interpolation of the added-mass and damping coefficients.

Data Card Set 23, one card, FORMAT (6I6)

This card contains the following six integer variables:

(1) ML, column 6, is a control for the motion and load calculations.

ML = 1, only motions are calculated.

ML = 2, both motions and loads are calculated.

ML must be defined.

(2) IEND, column 12, is a control for including endterms in the equations of motion.

IEND = 1, end terms will be included. Set IXAST = NST-2 (Data Card Set 15).

IEND = 2, no end terms.

IEND must be defined.

(3) IBILGE, column 18, controls reading in Data Card Sets 27 -28 which contain bilge keel information required by the program for computing the viscous roll-damping coefficient when Option 1 or Method 2 of Option 2 is used. (For definitions of the options see Section IIIA.3.)

IBILGE = 1, the ship has bilge keels. Read in Data Card Sets 27-28. See IDAMP and IPRCNT (integers 5 and 6 of this Data Card Set) for choice of option and method.

IBILGE = 2, no bilge keels. Skip Data Card Sets 27-28.

IBILGE must be defined.

(4) IPRES, column 24, is a control for the pressure calculations. It also controls reading in Data Card Set 29.

IPRES = 1, calculate pressures for the stations specified by Data Card Set 29.

IPRES = 2, no pressure calculations. Skip Data Card Set 29.

IPRES must be defined.

(5) IDAMP, column 30, is a control integer used to specify the option used to compute the viscous roll-damping coefficients. It also controls reading in Data Card Sets 32-34.

IDAMP = 1, Option 1 will be used and the total and sectional viscous roll-damping coefficients will be computed by the program using information supplied in Data Card Sets 25-28.

IDAMP = 2 (Future option), Option 2 will be used and the total viscous roll-damping coefficients will be read in from Data Card Set 32. See IPRCNT (next integer description) for the choice of method for determining the sectional coefficients.

IDAMP = 3 (Future option), Option 3 will be used and the program will determine the total and sectional viscous roll-damping coefficients from defined classes of ships. The class of ship is specified in Data Card Set 34.

IDAMP undefined, program will assume IDAMP = 1. If IDAMP = 1, Data Card Sets 32-34 will not be read in.

(6) IPRCNT, column 36, is a control integer used to specify the method used in Option 2 to determine the sectional viscous roll-damping coefficients.

IPRCNT = 1, Method 1 is used and the percentage of the sectional roll-damping is supplied in Data Card Set 33.

IPRCNT = 2, Method 2 is used. The program computes the percentages. Skip Data Card Set 33.

See Section III.A.3 – Viscous Roll-Damping Input and Table 3 for a discussion of the various Options and Methods.

Data Card Set 24, one card, FORMAT (F10.8, 2F10.4, I6)

This card contains three floating point numbers and one integer.

(1) VNY, columns 1 - 10, it is the kinematic viscosity of water, ν, in units consistent with the WORD length unit. For fresh water at 70°F, $\nu = 1.059 \times 10^{-5}$ $FT^2 \cdot SEC$.

(2) GRAV, columns 11 - 20, is the acceleration due to gravity in units consistent with the WORD length unit. For instance, if WORD = FEET, GRAV = 32.2 feet $\cdot$ seconds^{-2}

(3) AMODL, columns 21 - 30, is the total length of the submerged portion of the hull. It is used by the program for the calculation of the Reynolds number.

(4) MOD, column 36, is a control integer for the type of flow around the hull.

MOD = 1, laminar flow around the hull is assumed.

MOD = 2, turbulent flow around the hull is assumed.

MOD must be defined.

Most cases require specification of turbulent flow. For small ships at slow speeds the flow may be laminar. Note–VNY, MODL, and MOD are required only when the *program* computes the roll damping (Option 1 or Method 2 of Option 2).

The next four Data Card Sets, 25 through 28, are not included when IDAMP = 2. They contain information the program uses to calculate roll damping.

Data Card Set 25, from one to two cards, FORMAT (16I5)

This card set contains the NST-2 control integers, ITS(I), one for each station except the extreme forward and extreme aft stations. The values of ITS(I) are used in the calculation of roll induced eddymaking. They specify the local hull shapes at Section I and are determined according to the following procedure:

(1) ITS(I) = 1, Section I has a V or U shape with a small radius at the keel (bow sections).

(2) ITS(I) = 2, Section I has a sectional area coefficient greater than 0.95 (parallel midbody with rectangular shapes).

(3) ITS(I) = 3, Section I has a shallow V or U shape with a local beam/draft ratio greater than 1.0 (aft sections of destroyers or cruisers).

(4) ITS(I) = 4, Section I has an extremely rounded shape (a destroyer hull section with extremely rounded bilges and no skeg).

Note that ITS is punched in I5 fields.

Data Card Set 26, from one to four cards, FORMAT (8F10.4)

This card set contains the NST-2 bilge radii, RD(I), in WORD units, one for each station except the extreme forward and extreme aft stations. RD(I) is defined as follows:

RD(I) = radius of bilge circle at Section I for,

(1) sections that have bilge keels,

and (2) sections with ITS(I) = 2.

RD(I) = 1.0 otherwise.

The next two Data Card Sets, 27 and 28, are included only if the ship has bilge keels (IBILGE = 1).

Data Card Set 27, one card, FORMAT (2F10.4)

This card contains the following two bilge keel parameters:

(1) AKEELL, columns 1 - 10, is the total length of the bilge keel in WORD units.

(2) BEAMKL, columns 11 - 20, is the maximum width of the bilge keel in WORD units.

Data Card Set 28, NST-2 number of cards, FORMAT (6F10.4)

This data card set provides a description of the bilge keel at each of the NST-2 stations. The extreme fore and aft stations are not considered. Each card contains the following six numbers (see Figure 8):

(1) RFD(I), columns 1 - 10, is the deadrise of Section I in WORD units. Set equal to 0.0 for stations with no bilge keels.

(2) DELTAD(I), columns 11 - 20, is the length of the bilge keel along Section I in WORD units. Set equal to 0.0 for stations with no bilge keel. The program tests for 0.0 in this case in order to by-pass a number of calculations.

(3) RKD(I), columns 21 - 30, is the distance from the middle of the bilge keel at Section I to an axis through the center of gravity of the ship and parallel to the x-axis. It is in WORD units. Set equal to 1.0 for sections with no bilge keels.

(4) SD(I), columns 31 - 40, is the distance from the root of the bilge keel to the waterline as measured along the countour of the hull at Section I. It is in WORD units. Set equal to 1.0 for stations with no bilge keels.

(5) COSPHD(I), columns 41 - 50, is the cosine of the angle, α, between RKD(I) and the bilge keel at Section I. Set equal to 1.0 for sections with no bilge keels.

(6) PHID(I), columns 51 - 60, is the angle, Φ, in radians, formed by RKD(I) and a line connecting the center of gravity with the waterline at Section I. Set equal to 1.0 for sections with no bilge keels.

The next Data Card Set, 29, is included only if pressure calculations are desired (IPRES = 1).

Data Card Set 29, from one to four cards, FORMAT (8F10.4)

This card set contains the NST-2 control numbers, STPR(I), which determine at which sections the pressure distribution will be calculated. The program can compute the pressures for up to *eight* sections. There are two options:

STPR(I) = 0.0, the pressure on Section I will not be calculated; and

STPR(I) = 1.0, the pressure distribution will be calculated on Section I.

STPR(I) must be defined.

Data Card Set 30 Delete

The next Data Card Set, 31, is not included if roll damping coefficients are read in (IDAMP = 2).

Data Card Set 31, from one to seven cards, FORMAT (8F10.4)

This card set contains the NHF = NOH · NOB · NWSTP estimates of maximum roll angle (single amplitude), THMD(I), in radians. (See Data Card Set 16 for the definitions of NOH, NOB, and NWSTP.) The THMD(I) values are the initial values in the "trial and error" procedure used in solving the quasi-linear equations for roll. (See Equation 11 in Section IIA.) These estimates are functions of wave slope, Froude number and heading angle. Eight THMD(I) values are given per card in a sequential order given by varying the wave slope first, then the Froude number and finally the heading angle. If THMD(I) is undefined the program will supply initial estimates. If accurate estimates can be provided by the user, the run time will be reduced substantially. Note that due to storage restrictions NHF $\leq$ 50.

The next Data Card Set, 32, is included when roll damping coefficients are to be read in (IDAMP = 2).

Data Card Set 32, from one to two cards, FORMAT (8F10.4)

This card set contains the following two roll-damping coefficients as a function of Froude number:

(1) B2(I), columns 1 - 10, is the linear viscous roll damping coefficient for the first Froude number.

(2) B3(I), columns 11 - 20, is the nonlinear viscous-roll damping coefficient for the first Froude number. If more than one Froude number is given, the remainder of the card should be filled with pairs of numbers, B2(I) and B3(I).

The next Data Card Set, 33, is included only when the roll-damping coefficients are to be determined for each station by the user (load calculations are desired and IDAMP = 2). In this case, IPRCNT = 1.

Data Card Set 33, from one to fifty cards, FORMAT (8F10.4)

This card set contains the percentages of B2(I) and B3(I) to be used for each of NST-2 stations. There are up to two cards for each station (excluding the extreme fore and extreme aft stations). The order of input per card is the same as in Data Card Set 32.

(1) PB2(I,J), columns 1 - 10, is the percentage of the B2 coefficient as a function of Station I and Froude number J.

(2) PB3(I,J), columns 11 - 20, is the percentage of the B3 coefficient. Note that, if IPRCNT = 2, the program will determine these percentages and Data Card Set 33 will not be required.

The next Data Card Set, 34, is included only if IDAMP = 3.

Data Card Set 34, one card, FORMAT (I6)

This card contains one control integer, ICLASS.

ICLASS, column 6, specifies the class of ship for which roll damping will be computed. The program will use stored values for the roll-damping coefficients as a function of ship class. The options are:

ICLASS = 1, small boats.

ICLASS = 2, high-speed transom-stern hulls.

ICLASS = 3, moderate-speed cruiser-stern hulls.

If data cards for another ship are to be included, first repeat Data Card Set 2 using IPASS = GOGO, followed by Data Card Sets 3 - 34 for the next ship. When no more ships are to be run, repeat Data Card Set 2 with IPASS = STOP. This completes the data card input for the program.

Commonly Used Equations	
Encounter frequency	$\omega_E = \omega - \dfrac{\omega^2 V}{g} \cos \mu$
Nondimensional ω_E	$\omega_{EN} = \omega_E \cdot \sqrt{L_{pp}/g}$
Wave frequency	$\omega = \sqrt{\dfrac{2\pi g}{\lambda}}$
Froude number	$F_n = \dfrac{V}{\sqrt{g\, L_{pp}}}$
Wave slope	$WS = \dfrac{360 \cdot \zeta_A}{\lambda}$

V	is the ship speed in feet/second
g	is the acceleration due to gravity
μ	is the heading angle
λ	is the wavelength
ζ_A	is the wave amplitude
L_{pp}	is the length between perpendiculars

APPENDIX C

Listing of the DTNSRDC Hullborne Hydrofoil Six-Degree of Freedom Motion Prediction Computer Program (see Ref. 3)

```
C                                                                       LK0
C------VERSION 4  -  CDC 6700  -  H A N S E L  -  'JNE, 1972            LK0
C                                                                       LK0
C------NAVSHIPS-RANDCEN SHIP-MOTION AND SEA-LOAD COMPUTER PROGRAM--------- LK0
C                                                                       LK0
C                                                                       LK0
C------VERSION 0  -  N.SALVESEN,NSRDC  W.FRANK,NSRDC  O.FALTINSEN,DNV    LK0
C                 -                                                     LK0
C------VERSION 1  -  UPDATED AND CONVERTED TO RUN ON THE UNIVAC 1108---- LK0
C                 -  AT NBS BY DAN SHERIDAN, 1970----------------------- LK0
C------VERSION 2  -  UPDATED ON UNIVAC 1108 AT NBS BY BILL MEYERS------- LK0
C                 -  DEC, 1970---------------------------------------- LK0
C------VERSION 3  -  UPDATED AND CONVERTED TO RUN ON CDC 6700----------- LK0
C                 -  AT NSRDC BY BILL MEYERS, JUNE, 1971---------------- LK9
C------VERSION 4  -  LOAD OUTPUT MODIFIED, SEQUENTIAL STORAGE OF-------- LK9
C                 -  PAA AND PAV  -  BILL MEYERS, JUNE, 1972------------ LKC
C                                                                       LK0
      OVERLAY (LINK0,0,0)                                               LK0
      PROGRAM HANSEL (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,             LK0
     2               TAPE1,TAPE10,TAPE20)                               LK0
      COMMON DUM1(2720),PRNTLP,LC42(356)                                LK0
      COMMON /TEMP/ DUM3(5000)                                          LK0
      COMMON /LOAFRN/ STLC(24),NOR02,NOR03,IDAMP,IPRCNT,B2(5),B3(5),    LK9
     2 PS2(25,5),PS3(25,5),ICLASS                                       LK0
      COMMON /PFOIL/ DUMS(93),IPRINT                                    FM00
      COMMON /DFOIL/ DUM6(36)                                           FM00
      DATA ISTOP /4HSTOP/                                               LK0
 1000 FORMAT (1H1,27(/),55X,19H*   H A N S E L   *)                     LK0
 1004 FORMAT (     3A10)                                                LK0
 1006 FORMAT (//50X,3A10)                                               LK0
 1008 FORMAT (12X,3A10)                                                 LK0
 1010 FORMAT (1H1,40X,31HLISTING OF ALL INPUT DATA CARDS/)              LK0
 1020 FORMAT (21X,1H1,9X,1H2,9X,1H3,9X,1H4,9X,1H5,9X,1H6,9X,1H7,9X,1H8/ LK9
     24X,6HCOLUMNS ,8(10H1234567890)/)                                  LK0
 1030 FORMAT (5X,A4,7X,A3,8X,A3)                                        LK0
 1040 FORMAT (12X,*PASS=*,A4,*  TAPE=*,A3,*  PRINT=*,A3)                LK0
 1050 FORMAT (10X,*VERSION 3  -  CDC 6700  -  H A N S E L  -  JUNE, 19* LK9
     2 *71*/10X,*NSRDC SHIP-MOTION AND SEA-LOAD COMPUTER PROGRAM*       LK0
     2 /20X,3A10,                                                       LK0
     2 //10X,*FILE*,I3,*    800 OUTPUT TAPE     HI=HIGH DENSITY (556)*/) LK0
 1060 FORMAT (1H1,27(/),60X,13H*   E N D   *)                           LK0
      CALL FTNBIN (1,1,10)                                              LK0
      CALL FTNBIN (1,1,20)                                              LK0
      REWIND 1                                                          LK0
      NPASS = 0                                                         LK0
      WRITE (6,1000)                                                    LK0
C---------------------------------------------------------------------- LK0
C     DATA CARD SET 1                                                   LK0
C---------------------------------------------------------------------- LK0
      READ  (5,1004) NAME1,NAME2,NAME3                                  LK0
      WRITE (6,1006) NAME1,NAME2,NAME3                                  LK0
   10 NPASS = NPASS + 1                                                 LK0
      WRITE (6,1010)                                                    LK0
      WRITE (6,1020)                                                    LKC
      IF (NPASS .EQ. 1) WRITE (6,1008) NAME1,NAME2,NAME3                LK0
C---------------------------------------------------------------------- LK0
C     DATA CARD SET 2                                                   LK0
```

```
C-----------------------------------------------------------------------
      READ  (5,1030) IPASS,OTAPE,PRNTOP
      WRITE (6,1040) IPASS,OTAPE,PRNTOP
      IF (IPASS .EQ. ISTOP) GO TO 20
      IF (NPASS .EQ. 1) CALL SKIP (OTAPE,NSKIP)
      IF (NPASS .GT. 1) CALL SKPFIL (1,-1)
      NFILE = NSKIP + NPASS
      WRITE (1,1050) NAME1,NAME2,NAME3,NFILE
      CALL SEPART (2)
      CALL OVERLAY (5HLINK1,1,0)
      CALL OVERLAY (5HLINK2,2,0)
      CALL OVERLAY (5HLINK3,3,0)
      ENDFILE 1
      K = NFILE + 1
      WRITE (1,1050) NAME1,NAME2,NAME3,K
      CALL SEPART (2)
      GO TO 10
   20 ENDFILE 1
      REWIND 1
      WRITE (6,1060)
      STOP
      END
C
C------VERSION 4  -  CDC 6700  -  S K I P  -  JUNE, 1972----------------
C
      SUBROUTINE SKIP (OTAPE,L)
      INTEGER OTAPE,OLD,TITLE,ENDTAP,ENDGRO
      DATA OLD /3HOLD/, ENDTAP /10HEND OF TAP/, ENDGRO /10HEND OF GRO/
 1000 FORMAT (A10)
 2000 FORMAT (*1 *,I3,* FILES SKIPPED ON OUTPUT TAPE*)
      L = 0
      IF (OTAPE .NE. OLD) GO TO 30
   10 READ (1,1000) TITLE
      IF (TITLE .EQ. ENDGRO) GO TO 20
      IF (TITLE .NE. ENDTAP) GO TO 10
      CALL SKPFIL (1,-1)
      GO TO 30
   20 L = L + 1
      CALL SKPFIL (1,1)
      GO TO 10
   30 WRITE (6,2000) L
      RETURN
      END
C
C------VERSION 4  -  CDC 6700  - S E P A R T  -  JUNE, 1972-------------
C
      SUBROUTINE SEPART (N)
 1000 FORMAT (/*END OF GROUP*,2(4X,A10),2X,F10.3/)
 1010 FORMAT ( *END OF TAPE *,2(4X,A10),2X,F10.3)
      CDATE = DATE (D)
      CTIME = TIME (E)
      ATIME = SECOND (A)
      IF (N .EQ. 1) WRITE (1,1000) CDATE,CTIME,ATIME
      IF (N .EQ. 1) GO TO 10
      WRITE (1,1010) CDATE,CTIME,ATIME
      WRITE (1,1010) CDATE,CTIME,ATIME
      BACKSPACE 1
   10 RETURN
      END
C
C------VERSION 4  -  CDC 6700  - S I M P U N  -  JUNE, 1972-------------
C
      FUNCTION SIMPUN(X,Y,N)
C
C     FORTRAN IV FUNCTION FOR SIMPSONS RULE INTEGRATION
C     EQUAL OR UNEQUAL INTERVALS,W.FRANK
C
      DIMENSION X(50),Y(50)
    2 FORMAT(23HCNON MONOTONE X SIMPUN  I4,1PE12.4)
      IF(N-2) 7,5,4
    5 S=(Y(1)+Y(2))*(X(2)-X(1))/2.
      GO TO 6
    7 S=0.
      GO TO 6
```

```
    4 M=N-1
      S=(X(2)-X(1))/6.*(Y(1)*((X(2)-X(3))/(X(1)-X(3))+2.)+Y(2)*((X(1)-X(
     13))/(X(2)-X(3))+2.)-Y(3)*(X(2)-X(1))**2/((X(1)-X(3))*(X(2)-X(3))))
      LB=2
      IF(N-3) 8,8,9
    9 S=S+(X(3)-X(2))/6.*(Y(2)*((X(3)-X(4))/(X(2)-X(4))+2.)+Y(3)*((X(2)-
     1X(4))/(X(3)-X(4))+2.)-Y(4)*(X(3)-X(2))**2/((X(2)-X(4))*(X(3)-X(4))
     2))
      LB=3
    8 DO 1 K=LB,M
      XDIFF=ABS(X(K+1)-X(1))
      XDIFF1=ABS(X(K)-X(1))
      IF(XDIFF-XDIFF1)  3,11,11
    3 WRITE(6,2) K,X(K)
      GO TO 7
   11 CONTINUE
      AB=(X(K+1)-X(K))/6.
      AC=Y(K)*((X(K+1)-X(K-1))/(X(K)-X(K-1))+2.)
      AD=Y(K+1)*((X(K)-X(K-1))/(X(K+1)-X(K-1))+2.)
      AE=Y(K-1)*(X(K+1)-X(K))**2/((X(K)-X(K-1))*(X(K+1)-X(K-1)))
    1 S=S+AB*(AC+AD-AE)
    6 SIMPUN=S
      RETURN
      END
C
C------VERSION 4  -  CDC 6700  - M A T I N S  -  JUNE, 1972-------------
C
      SUBROUTINE MATINS(A,NR,N1,B,NC,M1,DETERM,ID,INDEX)
C
C PROGRAMMER- S. GOOD,NSRDC
C
      EQUIVALENCE (IROW,JROW),(ICOLUM,JCOLUM),(AMAX,T,SWAP)
      DIMENSION A(NR,NR),B(NR,NC),INDEX(NR,3)
C
C     INITIALIZATION
C
      N=N1
      M=M1
      DETERM=0.0
      DO 20 J=1,N
   20 INDEX(J,3)=0
      DO 550 I=1,N
C
C     SEARCH FOR PIVOT ELEMENT
C
      AMAX=0.0
      DO 105 J=1,N
      IF(INDEX(J,3)-1) 60,105,60
   60 DO 100 K=1,N
      IF(INDEX(K,3)-1) 80,100,715
   80 IF(AMAX-ABS(A(J,K))) 85,100,100
   85 IROW=J
      ICOLUM=K
      AMAX=ABS(A(J,K))
  100 CONTINUE
  105 CONTINUE
      INDEX(ICOLUM,3)=INDEX(ICOLUM,3)+1
      INDEX(I,1)=IROW
      INDEX(I,2)=ICOLUM
C
C     INTERCHANGE ROWS TO PUT PIVOT ELEMENT ON DIAGONAL
C
      IF(IROW-ICOLUM) 140,310,140
  140 DETERM=-DETERM
      DO 200 L=1,N
      SWAP=A(IROW,L)
```

```
      A(IROW,L)=A(ICOLUM,L)
  200 A(ICOLUM,L)=SWAP
      IF(M) 310,310,210
  210 DO 250 L=1,M
      SWAP=B(IROW,L)
      B(IROW,L)=B(ICOLUM,L)
  250 B(ICOLUM,L)=SWAP
C
C     DIVIDE PIVOT ROW BY PIVOT ELEMENT
C
  310 PIVOT=A(ICOLUM,ICOLUM)
      DETERM=DETERM*PIVOT
  330 A(ICOLUM,ICOLUM)=1.0
      DO 350 L=1,N
  350 A(ICOLUM,L)=A(ICOLUM,L)/PIVOT
      IF(M) 380,380,360
  360 DO 370 L=1,M
  370 B(ICOLUM,L)=B(ICOLUM,L)/PIVOT
C
C     REDUCE NON-PIVOT ROWS
C
  380 DO 550 L1=1,N
      IF(L1-ICOLUM) 400,550,400
  400 T=A(L1,ICOLUM)
      A(L1,ICOLUM)=0.0
      DO 450 L=1,N
  450 A(L1,L)=A(L1,L)-A(ICOLUM,L)*T
C
C
      IF(M) 550,550,460
  460 DO 500 L=1,M
  500 B(L1,L)=B(L1,L)-B(ICOLUM,L)*T
  550 CONTINUE
C
C     INTERCHANGE COLUMNS
C
      DO 710 I=1,N
      L=N+1-I
      IF(INDEX(L,1)-INDEX(L,2)) 630,710,630
  630 JROW=INDEX(L,1)
      JCOLUM=INDEX(L,2)
      DO 705 K=1,N
      SWAP=A(K,JROW)
      A(K,JROW)=A(K,JCOLUM)
      A(K,JCOLUM)=SWAP
  705 CONTINUE
  710 CONTINUE
      DO 730 K=1,N
      IF(INDEX(K,3)-1) 715,720,715
  720 CONTINUE
  730 CONTINUE
      ID=1
  810 RETURN
  715 ID=2
      GO TO 810
      END
C
C------VERSION 4  -  CDC 6700  - P R O 1  -  JUNE, 1972-----------------
C
       OVERLAY (LINK1,1,0)
       PROGRAM PRO1
       CALL PRGM1
       END
```

```
C                                                                         PR1
C------VERSION 4  -  CDC 6700  - P R G M 1  -  JUNE, 1972--------------- PR1
C                                                                         PR1
      SUBROUTINE PRGM1                                                    PR1
C                                                                         PR1
C PROGRAMMER- O. FALTINSEN,DNV                                            PR1
C                                                                         PR1
      COMMON AM(27),NUT,NMAS,NOS,ST(25),DS(25),EL,ELL,X(25,8),Y(25,8),PM PR1
     1AS(27),XMAS(27),ZMAS(27),RKG(27),XG,ZG,TMAS,E144,E155,E156,E146,TP PR1
     2ST,RF33,RM35,RM55,CGM,DIP,K,N,TVOL,ALFA(40,11),BETA(40,11),HCG(10) PR1
     3,FN(5),BAM(30),CDG(10),SDG(10),OMAX,OMIN,NFR,NOK,NOB,NOH,OME.(40),  PR1
     4FK(7,6),XX(25,7),YY(25,7),DEL(25,7),SNE(25,7),CSE(25,7),EN1(25,7),  PR1
     5UN,OMEGA,IJ,TITO(12),WORD,NUN,IXAST,HOG1(10),IT,LBV,CPC,PRNTOP     PR1
      COMMON ST1(27),YMAS(27),BEAM,CRAFT,UMAX,IRR,FL,ILNC,IBILGE,IPRES,  PR1
     2VNY,GRAV,AMOUL,HOD,AKELLL,BEAMKL,ITS(25),RO(25),RFL(25),DELTAO(25) PR1
     2,RKD(25),SD(25),COSPHC(25),PHIC(25),STPK(25),THMD(50)              PR1
      COMMON NHSTP,INHSTP(12)                                             PR1
       COMMON /TEMP/ ST2(29),DS1(27),XMAS1(27),SQAR(27),SAS(27),HBM(27),  PR1
     2 HB3(27),SS(27),XI(8),YI(8),XY(8),SHB(27),HSB(27),DUM3(4704)       PR1
       COMMON /LODPRN/ STLD(24),WORD2,WORD3,IDAMP,IPRCNT,B2(5),B3(5),     PR1
     2 PB2(25,5),PB3(25,5),ICLASS                                         PR1
      COMMON /PFOIL/ IFOIL,RHO,NF,CPL(10),SPAN(10),CHORD(10),S(10),YF(10 FMOD
     2),ZF(10),DGAMMA(10),CLZ(10),ASP(10),IPRINT                         FMOD
C                                                                         PR1
C READ AND PRINT ALL DATA CARD INPUT                                      PR1
C WRITE ALL DATA CARD INPUT ON BCD OUTPUT TAPE                            PR1
C                                                                         PR1
  299 FORMAT (1H1,12A6)                                                   PR1
 1000  FORMAT (10X,*SHIP DATA CARD INPUT TO HANSEL*)                      PR1
 8005 FORMAT (1H1,40X,31HLISTING OF ALL INPUT DATA CARDS/)                PR1
 8007 FORMAT (21X,1H1,9X,1H2,9X,1H3,9X,1H4,9X,1H5,9X,1H6,9X,1H7,9X,1H8/  PR1
     24X,8HCOLUMNS ,8(10H1234567890)/)                                    PR1
 8008 FORMAT (//24H  END OF DATA CARD INPUT)                              PR1
 8009 FORMAT ( /27H ...CONTINUED ON NEXT PAGE.)                           PR1
 8002 FORMAT (5X,A3,8X,A3)                                                PR1
 8004  FORMAT (     2A6,A8)                                               PR1
 8006  FORMAT (12X,2A6,A8)                                                PR1
 8000 FORMAT (     12A6)                                                  PR1
 8010 FORMAT (12X,12A6)                                                   PR1
 8020 FORMAT (     12I6)                                                  PR1
 8030 FORMAT (12X,12I6)                                                   PR1
 8032 FORMAT (     F10.4,4F10.6,F10.4)                                    PR1
 8034 FORMAT (12X,F10.4,4F10.6,F10.4)                                     PR1
 8040 FORMAT (     8F10.4)                                                PR1
 8050 FORMAT (12X,8F10.4)                                                 PR1
 8060 FORMAT (     I5,2F10.4)                                             PR1
 8070 FORMAT (12X,I5,2F10.4)                                              PR1
 8080 FORMAT (     F10.8,2F10.4,I6)                                       PR1
 8090 FORMAT (12X,F10.8,2F10.4,I6)                                        PR1
 8100 FORMAT (     16I5)                                                  PR1
 8110 FORMAT (12X,16I5)                                                   PR1
      WRITE (6,8005)                                                      PR1
      WRITE (6,8007)                                                      PR1
       BACKSPACE 1                                                        PR1
       CALL SEPART (1)                                                    PR1
       WRITE (1,1000)                                                     PR1
C------------------------------------------------------------------------ PR1
```

```
C       DATA CARD SET 3
C-----------------------------------------------------------------------
      READ  (5,8000) TITO
      WRITE (6,8010) TITO
      WRITE (1,8000) TITO
C-----------------------------------------------------------------------
C       DATA CARD SET 4
C-----------------------------------------------------------------------
       READ  (5,8004) WORD,WORD2,WORD3
       WRITE (6,8006) WORD,WORD2,WORD3
       WRITE (1,8004) WORD,WORD2,WORD3
C-----------------------------------------------------------------------
C       DATA CARD SET 5
C-----------------------------------------------------------------------
      READ  (5,8020) NUT,NST,NMAS,IT
      WRITE (6,8030) NUT,NST,NMAS,IT
      WRITE (1,8020) NUT,NST,NMAS,IT
       NUS = NST - 2
       M2 = NST
C-----------------------------------------------------------------------
C       DATA CARD SET 6
C-----------------------------------------------------------------------
      READ  (5,8040) (ST1(I),I=1,M2)
      WRITE (6,8050) (ST1(I),I=1,M2)
      WRITE (1,8040) (ST1(I),I=1,M2)
C-----------------------------------------------------------------------
C       DATA CARD SET 7
C-----------------------------------------------------------------------
      READ  (5,8040) ELL,BEAM
      WRITE (6,8050) ELL,BEAM
      WRITE (1,8040) ELL,BEAM
      DO 9010 I=1,NUS
C-----------------------------------------------------------------------
C       DATA CARD SET 8
C-----------------------------------------------------------------------
      READ  (5,8040) (X(I,J),J=1,NUT)
      WRITE (6,8050) (X(I,J),J=1,NUT)
      WRITE (1,8040) (X(I,J),J=1,NUT)
      READ  (5,8040) (Y(I,J),J=1,NUT)
      WRITE (6,8050) (Y(I,J),J=1,NUT)
      WRITE (1,8040) (Y(I,J),J=1,NUT)
 9010  CONTINUE
      IF (IT .EQ. 0) GO TO 9020
C-----------------------------------------------------------------------
C       DATA CARD SET 9
C-----------------------------------------------------------------------
      READ  (5,8032) TMAS,EI44,EI55,EI66,EI46,ZG
      WRITE (6,8034) TMAS,EI44,EI55,EI66,EI46,ZG
      WRITE (1,8032) TMAS,EI44,EI55,EI66,EI46,ZG
       WRITE (6,8009)
       WRITE (6,299)
       WRITE (6,8007)
      GO TO 9030
C-----------------------------------------------------------------------
C       DATA CARD SET 10
C-----------------------------------------------------------------------
 9020 READ  (5,8040) (PMAS(I),I=1,NMAS)
```

```
      WRITE (6,8050) (PMAS(I),I=1,NMAS)                                 PR1
      WRITE (1,8040) (PMAS(I),I=1,NMAS)                                 PR1
C---------------------------------------------------------------------- PR1
C       DATA CARD SET 11                                                PR1
C---------------------------------------------------------------------- PR1
      READ  (5,8040) (XMAS(I),I=1,NMAS)                                 PR1
      WRITE (6,8050) (XMAS(I),I=1,NMAS)                                 PR1
      WRITE (1,8040) (XMAS(I),I=1,NMAS)                                 PR1
C---------------------------------------------------------------------- PR1
C       DATA CARD SET 12                                                PR1
C---------------------------------------------------------------------- PR1
      READ  (5,8040) (YMAS(I),I=1,NMAS)                                 PR1
      WRITE (6,8050) (YMAS(I),I=1,NMAS)                                 PR1
      WRITE (1,8040) (YMAS(I),I=1,NMAS)                                 PR1
C---------------------------------------------------------------------- PR1
C       DATA CARD SET 13                                                PR1
C---------------------------------------------------------------------- PR1
        WRITE (6,8009)                                                  PR1
        WRITE (6,299)                                                   PR1
        WRITE (6,8007)                                                  PR1
      READ  (5,8040) (ZMAS(I),I=1,NMAS)                                 PR1
      WRITE (6,8050) (ZMAS(I),I=1,NMAS)                                 PR1
      WRITE (1,8040) (ZMAS(I),I=1,NMAS)                                 PR1
C---------------------------------------------------------------------- PR1
C       DATA CARD SET 14                                                PR1
C---------------------------------------------------------------------- PR1
      READ  (5,8040) ( RRG(I),I=1,NMAS)                                 PR1
      WRITE (6,8050) ( RRG(I),I=1,NMAS)                                 PR1
      WRITE (1,8040) ( RRG(I),I=1,NMAS)                                 PR1
C---------------------------------------------------------------------- PR1
C       DATA CARD SET 15                                                PR1
C---------------------------------------------------------------------- PR1
 9030 READ  (5,8020) IXAST                                              PR1
      WRITE (6,8030) IXAST                                              PR1
      WRITE (1,8020) IXAST                                              PR1
C---------------------------------------------------------------------- PR1
C       DATA CARD SET 16                                                PR1
C---------------------------------------------------------------------- PR1
      READ  (5,8020) NOK,NOB,NOH,NWSTP                                  PR1
      WRITE (6,8030) NOK,NOB,NOH,NWSTP                                  PR1
      WRITE (1,8020) NOK,NOB,NOH,NWSTP                                  PR1
C---------------------------------------------------------------------- PR1
C       DATA CARD SET 17                                                PR1
C---------------------------------------------------------------------- PR1
      READ  (5,8020) (INWSTP(I),I=1,NWSTP)                              PR1
      WRITE (6,8030) (INWSTP(I),I=1,NWSTP)                              PR1
      WRITE (1,8020) (INWSTP(I),I=1,NWSTP)                              PR1
C---------------------------------------------------------------------- PR1
C       DATA CARD SET 18                                                PR1
C---------------------------------------------------------------------- PR1
      READ  (5,8040) (HOG1(I),I=1,NOH)                                  PR1
      WRITE (6,8050) (HOG1(I),I=1,NOH)                                  PR1
      WRITE (1,8040) (HOG1(I),I=1,NOH)                                  PR1
C---------------------------------------------------------------------- PR1
C       DATA CARD SET 19                                                PR1
C---------------------------------------------------------------------- PR1
      READ  (5,8040) (FN(I),I=1,NOB)                                    PR1
```

```
      WRITE (6,8050) (FN(I),I=1,NOB)                                    PR1
      WRITE (1,8040) (FN(I),I=1,NOB)                                    PR1
C---------------------------------------------------------------------- PR1
C       DATA CARD SET 20                                                PR1
C---------------------------------------------------------------------- PR1
      READ  (5,8040) (BAM(I),I=1,NCK)                                   PR1
      WRITE (6,8050) (BAM(I),I=1,NCK)                                   PR1
      WRITE (1,8040) (BAM(I),I=1,NCK)                                   PR1
C---------------------------------------------------------------------- PR1
C       DATA CARD SET 21                                                PR1
C---------------------------------------------------------------------- PR1
      READ  (5,8060) NFR,OMIN,OMAX                                      PR1
      WRITE (6,8070) NFR,OMIN,OMAX                                      PR1
      WRITE (1,8060) NFR,OMIN,OMAX                                      PR1
C---------------------------------------------------------------------- PR1
C       DATA CARD SET 22                                                PR1
C---------------------------------------------------------------------- PR1
      READ  (5,8020) IRR                                                PR1
      WRITE (6,8030) IRR                                                PR1
      WRITE (1,8020) IRR                                                PR1
C---------------------------------------------------------------------- PR1
C       DATA CARD SET 23                                                PR1
C---------------------------------------------------------------------- PR1
        READ  (5,8020) ML,IEND,IBILGE,IPRES,ICAMP,IPRCNT                PR1
        WRITE (6,8030) ML,IEND,IBILGE,IPRES,ICAMP,IPRCNT                PR1
        WRITE (1,8020) ML,IEND,IBILGE,IPRES,ICAMP,IPRCNT                PR1
C---------------------------------------------------------------------- PR1
C       DATA CARD SET 24                                                PR1
C---------------------------------------------------------------------- PR1
      READ  (5,8080) VNY,GRAV,AMODL,MOD                                 PR1
      WRITE (6,8090) VNY,GRAV,AMODL,MOD                                 PR1
      WRITE (1,8080) VNY,GRAV,AMODL,MOD                                 PR1
        IF (ICAMP .EQ. 2) GO TO 9045                                    PR1
C---------------------------------------------------------------------- PR1
C       DATA CARD SET 25                                                PR1
C---------------------------------------------------------------------- PR1
      READ  (5,8100) (ITS(I),I=1,NOS)                                   PR1
      WRITE (6,8110) (ITS(I),I=1,NOS)                                   PR1
      WRITE (1,8100) (ITS(I),I=1,NOS)                                   PR1
C---------------------------------------------------------------------- PR1
C       DATA CARD SET 26                                                PR1
C---------------------------------------------------------------------- PR1
      READ  (5,8040) (RO(I),I=1,NOS)                                    PR1
      WRITE (6,8050) (RO(I),I=1,NOS)                                    PR1
      WRITE (1,8040) (RO(I),I=1,NOS)                                    PR1
      IF (IBILGE .EQ. 2) GO TO 9050                                     PR1
C---------------------------------------------------------------------- PR1
C       DATA CARD SET 27                                                PR1
C---------------------------------------------------------------------- PR1
      READ  (5,8040) AKEELL,BEAMKL                                      PR1
      WRITE (6,8050) AKEELL,BEAMKL                                      PR1
      WRITE (1,8040) AKEELL,BEAMKL                                      PR1
      DO 9040 I=1,NOS                                                   PR1
C---------------------------------------------------------------------- PR1
C       DATA CARD SET 28                                                PR1
C---------------------------------------------------------------------- PR1
      READ  (5,8040) RFO(I),DELTAD(I),RKO(I),SO(I),COSPHO(I),PHIC(I)    PR1
```

```
      WRITE (6,8050) RFO(I),CELTAO(I),RKO(I),SO(I),COSPHO(I),PHIO(I)
      WRITE (1,8040) RFO(I),DELTAO(I),RKO(I),SO(I),COSPHO(I),PHIO(I)
 9040  CONTINUE
 9045  CONTINUE
C-----------------------------------------------------------------------
C       DATA CARD SET 29
C-----------------------------------------------------------------------
 9050 IF (IPRES .EQ. 1) READ  (5,8040) (STPR(I),I=1,NOS)
      IF (IPRES .EQ. 1) WRITE (6,8050) (STPR(I),I=1,NOS)
      IF (IPRES .EQ. 1) WRITE (1,8040) (STPR(I),I=1,NOS)
       NOSM1 = NOS - 1
C-----------------------------------------------------------------------
C       DATA CARD SET 30
C-----------------------------------------------------------------------
       IF (IT .EQ. 0) READ  (5,8040) (STLD(I),I=1,NOSM1)
       IF (IT .EQ. 0) WRITE (6,8050) (STLD(I),I=1,NOSM1)
       IF (IT .EQ. 0) WRITE (1,8040) (STLD(I),I=1,NOSM1)
      NHF = NOH*NOB*NWSTP
       IF (IDAMP .EQ. 2) GO TO 9052
C-----------------------------------------------------------------------
C       DATA CARD SET 31
C-----------------------------------------------------------------------
      READ  (5,8040) (THMO(I),I=1,NHF)
      WRITE (6,8050) (THMO(I),I=1,NHF)
      WRITE (1,8040) (THMO(I),I=1,NHF)
 9052  CONTINUE
       IF (IDAMP .LE. 0) IDAMP = 1
      IF(IDAMP-2) 9090,9055,9080
 9055  CONTINUE
C-----------------------------------------------------------------------
C       DATA CARD SET 32
C-----------------------------------------------------------------------
       READ  (5,8040) (B2(I),B3(I),I=1,NOB)
       WRITE (6,8050) (B2(I),B3(I),I=1,NOB)
       WRITE (1,8040) (B2(I),B3(I),I=1,NOB)
       IF (IFRONT .NE. 1) GO TO 9090
       DO 9070 I=1,NOS
C-----------------------------------------------------------------------
C       DATA CARD SET 33
C-----------------------------------------------------------------------
       READ  (5,8040) (PB2(I,J),PB3(I,J),J=1,NOB)
       WRITE (6,8050) (PB2(I,J),PB3(I,J),J=1,NOB)
       WRITE (1,8040) (PB2(I,J),PB3(I,J),J=1,NOB)
 9070  CONTINUE
       GO TO 9090
 9080  CONTINUE
C-----------------------------------------------------------------------
C       DATA CARD SET 34
C-----------------------------------------------------------------------
       READ  (5,8020) ICLASS
       WRITE (6,8030) ICLASS
       WRITE (1,8020) ICLASS
 9090  CONTINUE
  905 FORMAT(     I5,3F12.2)
  906 FORMAT(12X,I5,3F12.2)
  907 FORMAT(     I5,3F12.2)
  970 FORMAT(     F3.0,5F7.2,F5.0,F10.7,F5.1)
```

```
  971 FORMAT(12X,F3.0,5F7.2,F5.0,F10.7,F5.1)                              FMOD
  980 FORMAT(//13H  CARD SET 36)                                          FMOD
  990 FORMAT(//13H  CARD SET 37)                                          FMOD
 7001 FORMAT(2I4)                                                         FMOD
 7002 FORMAT(//22H  FOIL DATA CARD INPUT)                                 FMOD
 7003 FORMAT(//32H1 HYDROFOIL VESSEL WITH FOILS UP/)                      FMOD
 7004 FORMAT(//34H1 HYDROFOIL VESSEL WITH FOILS DOWN/)                    FMOD
 2212 FORMAT (/21X,1H1,9X,1H2,9X,1H3,9X,1H4,9X,1H5,9X,1H6,9X,1H7,9X,1H8/ FMOD
     24X,8HCOLUMNS ,8(10H1234567890))                                     FMOD
 2213 FORMAT(/14X,2HNF,9X,4HFVOL,8X,4HFXCB,8X,4HFZCB/)                    FMOD
 2214 FORMAT (/12X,3HCPL,3X,4HSPAN,2X,5HCHORD,3X,4HX(S),4X,1HY,6X,1HZ,2X FMOD
     2,6HDGAMMA,3X,3HCLZ,5X,3HASP/)                                       FMOD
C-----------------------------------------------------------------------  FMOD
C     DATA CARD SET 35                                                    FMOD
C-----------------------------------------------------------------------  FMOD
C     HYDROFOIL VESSEL WITH FOILS UP    -  IFOIL=1                        FMOD
C     HYDROFOIL VESSEL WITH FOILS DOWN -  IFOIL=2                         FMOD
C     PRINTOUT OF MATRIX EQUATIONS  (NO = 0 , YES = 1)                    FMOD
C                                                                         FMOD
      READ(5,7001) IFOIL,IPRINT                                           FMOD
      IF(IFOIL .NE. 2) IFOIL=1                                            FMOD
      WRITE(1,7001) IFOIL                                                 FMOD
      IF(IFOIL-1) 9091,9091,9092                                          FMOD
 9091 WRITE(6,7003)                                                       FMOD
      GO TO 9515                                                          FMOD
 9092 WRITE(6,7004)                                                       FMOD
      WRITE(6,7002)                                                       FMOD
      WRITE(6,2212)                                                       FMOD
C-----------------------------------------------------------------------  FMOD
C     DATA CARD SET 36                                                    FMOD
C-----------------------------------------------------------------------  FMOD
C     NUMBER OF INPUT FOIL ELEMENTS, DISPLACED VOLUME (WORD**3),          FMOD
C     LONGITUDINAL CENTER OF BOYANCY FROM F.P. AND VERTICAL CENTER OF     FMOD
C     BOYANCY FROM WATERLINE (WORD) OF THE ENTIRE HYDROFOIL SYSTEM        FMOD
C                                                                         FMOD
      READ(5,905) NF,FVOL,FXCB,FZCB                                       FMOD
      WRITE(6,980)                                                        FMOD
      WRITE(6,2213)                                                       FMOD
      WRITE(6,906) NF,FVOL,FXCB,FZCB                                      FMOD
      WRITE(1,907) NF,FVOL,FXCB,FZCB                                      FMOD
      WRITE(6,990)                                                        FMOD
      WRITE(6,2214)                                                       FMOD
      DO 100 I=1,NF                                                       FMOD
C-----------------------------------------------------------------------  FMOD
C     DATA CARD SET 37                                                    FMOD
C-----------------------------------------------------------------------  FMOD
C     FOIL ELEMENT IN VERTICAL CENTER PLANE (CPL=1. FOR YES, CPL=2. FOR   FMOD
C     NO) , HYDROFOIL ELEMENT SPAN (FT), CHORD (FT), COORDINATES X,Y,Z    FMOD
C     OF MIDPOINT (FT), DIHEDRAL ANGLE OF V-FOIL (DEG), VERTICAL LIFT     FMOD
C     SLOPE (WORD2/WORD), ASP IN THE FACTOR   AR/(AR+ASP)   FOR FINITE    FMOD
C     SPAN                                                                FMOD
C                                                                         FMOD
      READ(5,970)  CPL(I),SPAN(I),CHORD(I),S(I),YF(I),ZF(I),DGAMMA(I),CL FMOD
     2Z(I),ASP(I)                                                         FMOD
      WRITE(6,971) CPL(I),SPAN(I),CHORD(I),S(I),YF(I),ZF(I),DGAMMA(I),CL FMOD
     2Z(I),ASP(I)                                                         FMOD
      WRITE(1,970) CPL(I),SPAN(I),CHORD(I),S(I),YF(I),ZF(I),DGAMMA(I),CL FMOD
```

```
   2Z(I),ASP(I)
 100 CONTINUE
     WRITE(6,2212)
9515 CONTINUE
     WRITE (6,8008)
      XG = 0.
     FACT=0.017453293
C------ALGORITHM TO COMPUTE SECTION WIDTHS---------------------------
      EPS = 0.001
      K = 2
      SECTB = ST1(1)
      DIFF = ST1(2) - SECTB
      SECTE = ST1(2) + DIFF
      IF (SECTE .GT. (ST1(3)+EPS)) GO TO 956
      IF (ABS(SECTE-ST1(3)) .LE. EPS) SECTB = ST1(2) - 0.5*DIFF
      NOS = NST - 2
      DO 955 N=1,NOS
      K = N + 1
      ST(N) = ST1(K)
      DIFF = ST1(K) - SECTB
      SECTE = ST1(K) + DIFF
      IF ((K+1).EQ.NST .AND. SECTE.GT.(ST1(NST)+EPS)) GO TO 956
      IF ((K+1).LT.NST .AND. SECTE.GE.(ST1(K+1)-EPS)) GO TO 956
      DS(N) = SECTE - SECTB
      SECTB = SECTE
 955  CONTINUE
      GO TO 957
 956  WRITE (6,2000) ST1(K),ST1(K+1),SECTE
2000  FORMAT (*1     STATION NUMBER ERROR -*/13X,*SECTION ASSOCIATED *
    2 *WITH STATION*,F8.3,* INCLUDES STATION*,F8.3,*.*/13X,
    2 *END OF SECTION =*,F8.3,*.  CORRECT STATION NUMBERS AND RERUN.*/
    2 28X,*- PROGRAM STOP -*)
      STOP
 957  CONTINUE
C
C  NUT=NUMBER OF OFFSETPOINTS FOR EACH SECTION
C  NMAS=NUMBER OF MASSPOINTS
C  NOS=NUMBER OF STATIONS
C  IT=0 MEANSOINERTIAMOMENTS,MASS AND CENTER OF GRAVITY FOR EACH SECTION
C       IS INPUT
C  ST=THE DISTANCE FROM FORWARD PERPENDICULAR TO THE STATIONS
C  DS=THE LENGTH OF THE STATIONS
C   BEAM=THE BEAM OF THE SHIP
C
     EL=ELL/2.0
     EL2=EL*EL
     EL3=EL2*EL
     DRAFT = ABS(Y(10,NUT))
     DO 9060 I=1,M2
     J = ST1(I) + .0001
9060 IF (J .EQ. 10) DRAFT = ABS(Y(I-1,NUT))
     DMAX = DRAFT
     DO 5 K=1,NOS
     DO 5 J=1,NUT
     TERM = ABS(Y(K,J))
   5 IF (DMAX .LT. TERM) DMAX = TERM
     DO 200  K=1,NOS
```

```
      DS(K)=DS(K)*ELL/20.                                               PR1
      ST(K)=ST(K)*ELL/20.                                               PR1
  200 CONTINUE                                                          PR1
      IF(IT) 70,71,70                                                   PR1
   70 CONTINUE                                                          PR1
C                                                                       PR1
C  ZG=Z-COORDINATE OF CENTER OF GRAVITY WITH  RESPECT TO THE CHOSEN     PR1
C     COORDINATE-SYSTEM IN WATERPLANE                                   PR1
      GO TO 72                                                          PR1
   71 CONTINUE                                                          PR1
C                                                                       PR1
C  CALCULATE TOTAL MASS=TMAS                                            PR1
C  CALCULATE CENTER OF GRAVITY                                          PR1
C  CALCULATE MOMENTS OF INERTIA AND CENTRIFUGAL MOMENTS                 PR1
C                                                                       PR1
      TMAS=0.0                                                          PR1
      XG=0.0                                                            PR1
      ZG=0.0                                                            PR1
      DO 9 I=1,NMAS                                                     PR1
      TMAS=TMAS+PMAS(I)                                                 PR1
      XG=XG+PMAS(I)*XMAS(I)                                             PR1
      ZG=ZG+PMAS(I)*ZMAS(I)                                             PR1
    9 CONTINUE                                                          PR1
      XG=XG/TMAS                                                        PR1
      ZG=ZG/TMAS                                                        PR1
      EI44=0.0                                                          PR1
      EI55=0.0                                                          PR1
      EI66=0.0                                                          PR1
      EI46=0.0                                                          PR1
      DO 10 I=1,NMAS                                                    PR1
      XMAS(I)=XMAS(I)-XG                                                PR1
   10 CONTINUE                                                          PR1
      DO 11 I=1,NMAS                                                    PR1
      ZO2=ZMAS(I)**2                                                    PR1
      EI44=EI44+PMAS(I)*(ZO2+RRO(I)**2)                                 PR1
      EI55=EI55+PMAS(I)*(ZO2+XMAS(I)**2)                                PR1
      EI66=EI66+PMAS(I)*(XMAS(I)**2+YMAS(I)**2)                         PR1
      EI46=EI46+PMAS(I)*XMAS(I)*ZMAS(I)                                 PR1
   11 CONTINUE                                                          PR1
      EI44=EI44/TMAS/ELL/ELL                                            PR1
      EI55=EI55/TMAS/ELL/ELL                                            PR1
      EI66=EI66/TMAS/ELL/ELL                                            PR1
      EI46=EI46/TMAS/ELL/ELL*(-1.)                                      PR1
   72 CONTINUE                                                          PR1
C                                                                       PR1
C  EI44=(ROLL-RADIUS OF GYRATION/L)**2                                  PR1
C  EI55=(PITCH-RADIUS OF GYRATION/L)**2                                 PR1
C  EI66=(YAW-RADIUS OF GYRATION/L)**2                                   PR1
C  EI46=CENTRIFUGAL-MOMENT-X-Z/MASS/L/L                                 PR1
C                                                                       PR1
C                                                                       PR1
C  CALCULATION OF HYDROSTATIC QUANTITIES                                PR1
C                                                                       PR1
      SOAK(1)=0.0                                                       PR1
      AM(1)=0.0                                                         PR1
      SAS(1)=0.0                                                        PR1
      HBM(1)=0.0                                                        PR1
```

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      HB3(1)=0.0
      HOM=NOS
      MAD=NOS+1
      MUD=MAD+1
      SQAR(MUD)=0.0
      AM(MUD)=0.0
      SAS(MUD)=0.0
       HOM(MUD) = 0.0
      HB3(MUD)=0.0
       SS(1) = ST1(1)/10.
       SS(MUD) = ST1(NST)/10.
      DO 13  K=2,MAD
      IP1=K-1
      SS(K)=ST(IP1)/EL
      DO 17 J=1,NUT
      XI(J)=X(IP1,J)/EL
      YI(J)=Y(IP1,J)/EL
      XY(J)=XI(J)*YI(J)
   17 CONTINUE
      SQAR(K)=2.0*ABS(SIMPUN(YI,XI,NUT))
      AM(K)=-2.0*SIMPUN(YI,XY,NUT)
      SAS(K)=SS(K)*SQAR(K)
      HB3(K)=2.*X(IP1,1)**3/EL3
   13 CONTINUE
      TVOL=SIMPUN(SS,SQAR,MUD)
      TPST=SIMPUN(SS,SAS,MUD)/TVOL
      TPCM=SIMPUN(SS,HB3,MUD)
      CBV=0.5*SIMPUN(SS,AM,MUD)/TVOL
      IF(IFOIL-1) 51,51,52
   52 FXCB=FXCB/EL
      FZCB=FZCB/ELL
      FVCL=FVOL/EL3
      HVOL=TVOL
      TVOL=HVOL+FVOL
      TPST=(TPST*HVOL+FXCB*FVOL)/TVOL
      CBV=(CBV*HVOL+FZCB*FVOL)/TVOL
   51 CONTINUE
      RHO=TMAS/(TVOL*EL3)
      CMC=CBV+TPCM/3.0/TVOL*0.5
C
C   TVOL=VOLUME OF THE HULL/(L/2)**3
C   TPST=LONGITUDINAL CENTER OF BOYANCY/(L/2)
C   CBV=VERTICAL CENTER OF BOYANCY/L
C   CMC=METACENTER HEIGHT OVER WATERPLANE/L
C
C
C   CALCULATION OF HEAVE-HEAVE,PITCH-PITCH,HEAVE-PITCH RESTORING COEFFICI
C
      DO 22  K=2,MAD
      IP1=K-1
      SS(K)=ST(IP1)/EL
      HBM(K)=X(IP1,1)/EL
   22 CONTINUE
      DO 26 K=1,MUD
      SPO=SS(K)-TPST
      SPO=-SPO
      SHB(K)=SPO*HBM(K)*(-1.)
```

```
      HSB(K)=SPD*SHB(K)*(-1.)                                           PR1
   26 CONTINUE                                                          PR1
      RF33=4.0*SIMPUN(SS,HBM,MUD)/TVOL                                  PR1
      RM35=-2.0*SIMPUN(SS,SHB,MUD)/TVOL                                 PR1
      RM55=SIMPUN(SS,HSB,MUD)/TVOL                                      PR1
      DGM=ABS(ZG/ELL-CMC)                                               PR1
      NON=NUT-1                                                         PR1
C                                                                       PR1
C   IXAST=NUMBER OF THE STATION WHERE SEPARATION IN WATERPLANE  BEGIN   PR1
C                                                                       PR1
      CALL PRINT1                                                       PR1
      RETURN                                                            PR1
      END                                                               PR1
```

```
C                                                                       PN1
C------VERSION 4  -  CDC 6700  -  P R I N T 1  -  JUNE, 1972------------PN1
C                                                                       PN1
      SUBROUTINE PRINT1                                                 PN1
      COMMON AM(27),NUT,NMAS,NOS,ST(25),DS(25),EL,ELL,X(25,8),Y(25,8),PMPN1
     1AS(27),XMAS(27),ZMAS(27),RRG(27),XG,ZG,TMAS,EI44,EI55,EI66,EI46,TPPN1
     2ST,RF33,RM35,RM55,DGM,DIP,K,N,TVOL,ALFA(40,11),BETA(40,11),HDG(10)PN1
     3,FN(5),BAM(30),CDG(10),SDG(10),OMAX,OMIN,NFR,NOK,NOB,NOH,OMEN(40),PN1
     4FR(7,6),XX(25,7),YY(25,7),DEL(25,7),SNE(25,7),CSE(25,7),EN1(25,7),PN1
     5UN,OMEGA,ID,TITO(12),WORD,NON,IXAST,HDG1(10),IT,CBV,CMC,PRNTOP    PN1
      COMMON ST1(27),YMAS(27),BEAM,DRAFT,DMAX,IRR,ML,IEND,IBILGE,IPRES, PN1
     2VNY,GRAV,AMODL,MOD,AKEELL,BEAMKL,ITS(25),RD(25),RFD(25),DELTAD(25)PN1
     2,RKD(25),SD(25),COSPHD(25),PHID(25),STPR(25),THMD(50)             PN1
      COMMON NWSTP,INWSTP(12)                                           PN1
       COMMON /TEMP/ ST2(29),DS1(27),XMAS1(27),SQAR(27),SAS(27),HBM(27),PN1
     2 HB3(27),SS(27),XI(8),YI(8),XY(8),SHB(27),HSB(27),DUM3(4704)      PN1
```

```
      COMMON /LODPRN/ STLD(24),WORD2,WORD3,IDAMP,IPRCNT,B2(5),B3(5),
    2 PB2(25,5),PB3(25,5),ICLASS
      INTEGER PRNTOP
      DATA MIN /3HMIN/
   10 FORMAT(20HONUMBER OF HEADINGS=I6)
   11 FORMAT(10H HEADING -8F10.4)
   12 FORMAT(26HONUMBER OF FROUDE NUMBERS=I6)
   13 FORMAT(16H FROUDE NUMBERS-8F10.4)
   14 FORMAT(*ONUMBER OF WAVE STEEPNESSES=*I6)
   15 FORMAT(* WAVE STEEPNESSES-*12I6)
   16 FORMAT(23HONUMBER OF WAVELENGTHS=I6)
   17 FORMAT(14H WAVELENGTH/L-8F10.4)
  299 FORMAT (1H1,12A6)
  300 FORMAT(///)
  301 FORMAT(103H DEFINITIONS, OUTPUT SCALING INFORMATION, DIMENSIONALIZ
     1ATION FACTORS, AND COORDINATE SYSTEM DESCRIPTION)
  302  FORMAT (* M=DISPLACED MASS      V=DISPLACED VOLUME       *
     2 *RO=DENSITY OF FLUID (M/V)        G=ACCELERATION OF GRAVITY*)
  303  FORMAT (* FN=FROUDE NUMBER        B=BEAM      L=LENGTH BETWEEN PERPE*
     2 *NDICULARS*/* AMPL.=AMPLITUDE      R=WAVE AMPLITUDE      LAM=WAVEL*
     2 *ENGTH      K=WAVE NUMBER (360 DEG/LAM)       K*,1H*,*R=WAVE SLOPE*/
     2* PHASE=PHASE LAG (DEGREES) WITH RESPECT TO THE MAXIMUM WAVE *
     2 *ELEVATION AT THE ORIGIN OF THE X,Y,Z COORDINATE SYSTEM,*)
  304  FORMAT (* WE=WAVE FREQUENCY OF ENCOUNTER (RAD/SEC)       *
     2 *WE(ND)= WE *,1H*,* SQRT(L/G)   (NONDIMENSIONAL)*)
  305 FORMAT(27H A(1,1)=ADDED MASS IN SURGE,4X,26H A(2,2)=ADDED MASS IN
     1SWAY,4X,27H A(3,3)=ADDED MASS IN HEAVE,4X,28H A(4,4)=ADDED MOMENT
     2IN ROLL)
  306 FORMAT(29H A(5,5)=ADDED MOMENT IN PITCH,4X,27H A(6,6)=ADDED MOMENT
     1 IN YAW,4X,47H A(3,5)=COUPLED ADDED MASS FOR PITCH INTO HEAVE)
  307 FORMAT(45H A(2,4)=COUPLED ADDED MASS FOR ROLL INTO SWAY,4X,44H A(2
     1,6)=COUPLED ADDED MASS FOR YAW INTO SWAY)
  308 FORMAT(46H A(4,6)=COUPLED ADDED MOMENT FOR YAW INTO ROLL)
  309 FORMAT(21H B(1,1)=SURGE DAMPING,4X,20H B(2,2)=SWAY DAMPING,4X,21H
     1B(3,3)=HEAVE DAMPING,4X,20H B(4,4)=ROLL DAMPING)
  310 FORMAT(21H B(5,5)=PITCH DAMPING,4X,19H B(6,6)=YAW DAMPING,4X,40H B
     1(3,5)=COUPLED PITCH INTO HEAVE DAMPING)
  311 FORMAT(38H B(2,4)=COUPLED ROLL INTO SWAY DAMPING,4X,37H B(2,6)=COU
     1PLED YAW INTO SWAY DAMPING,4X,37H B(4,6)=COUPLED YAW INTO ROLL DAM
     2PING)
  312 FORMAT(63H A(1,1),A(2,2) AND A(3,3) ARE DIMENSIONED WITH RESPECT T
     1O MASS.,2X,48H A(4,4),A(5,5),A(6,6) AND A(4,6) ARE DIMENSIONED)
  313 FORMAT(26H WITH RESPECT TO MASS*L*L.,2X,65H A(3,5),A(2,6) AND A(2,
     14) ARE DIMENSIONED WITH RESPECT TO MASS*L.)
  314 FORMAT(100H THE DAMPING COEFFICIENTS ARE DIMENSIONED WITH RESPECT
     1TO THE CORRESPONDING FACTORS * SQRT(G/L).      )
  315  FORMAT (*OEXCITING FORCES ARE SCALED BY *,7HM*G*R/L,*.      *
     2 *EXCITING MOMENTS ARE SCALED BY *,5HM*G*R,1H.)
  316  FORMAT (* SURGE,SWAY AND HEAVE MOTIONS ARE SCALED BY R.      *
     2 *ROLL,PITCH AND YAW MOTIONS ARE SCALED BY K*,3H*R./
     2 * SHEAR FORCES ARE SCALED BY *,10HRO*G*B*L*R,*.      MOMENTS ARE *
     2 *SCALED BY *,13HRO*G*B*L*L*R.)
  317 FORMAT(63H THE REFERENCE COORDINATE SYSTEM FOR THE MOTIONS IS AS F
     1OLLOWS-)
  318 FORMAT(114HOTHE ORIGIN IS ON THE CENTERLINE AND LIES IN THE LOAD W
     1ATER PLANE WITH A LONGITUDINAL LOCATION THE SAME AS THE CG.)
  319 FORMAT(76H THE X-AXIS IS ALONG THE CENTERLINE AND POSITIVE IN THE
     1DIRECTION OF THE AP.,2X,37H THE Y-AXIS IS POSITIVE TO STARBOARD.)
  320 FORMAT(32H THE Z-AXIS IS POSITIVE UPWARDS.)
  321 FORMAT(88HOTHE POSITIVE DIRECTIONS OF THE MOTIONS ARE THE SAME AS
     1THE POSITIVE DIRECTIONS OF AXES.)
  322 FORMAT(120H THE REFERENCE COORDINATE SYSTEM FOR SEA-LOADS HAS ITS
     1ORIGIN ON THE CENTERLINE OF THE STATION AND AXES PARALLEL TO THE )
  323 FORMAT(31H MOTION COORDINATE SYSTEM AXES.)
  431  FORMAT (* THE LENGTH DIMENSION USED=*,A6,*.      THE FORCE DIMENS*
     1TICS OF THE SHIP)
```

```
  2 FORMAT(8F10.4)
 33 FORMAT(20HONUMBER OF STATIONS=I6)
 36 FORMAT(133HODISTANCE FROM THE F.P. TO THE STATIONS USING A SCALE O
   1F L.B.P.=20.0 (A MINUS SIGN INDICATES THAT THE STATION IS FORWARD
   2OF THE F.P.))
 37 FORMAT(17H STATION SPACING-)
 39 FORMAT(37HONUMBER OF OFFSET POINTS PER STATION=I2)
 40 FORMAT(60H OFFSET POINTS(EXCLUDING THE EXTREME FORE AND AFT STATIO
   1NS)-)
 42 FORMAT(10H STATION  F8.3)
 43 FORMAT(4H Y- 8F10.4)
 44 FORMAT(4H Z- 8F10.4)
 45 FORMAT(23HONUMBER OF MASS POINTS=I6)
 46 FORMAT(25H MASS FOR EACH MASSPOINT-)
 47 FORMAT(69H MASS POINT COORDINATES IN THE MOTION REFERENCE SYSTEM(O
   1RIGIN AT CG).)
 48 FORMAT(4H Z- 8F10.4)
 31 FORMAT(31HOLENGTH BETWEEN PERPENDICULARS=F10.4)
325 FORMAT(17H BEAM AT MIDSHIP=F10.4)
 50 FORMAT(12H TOTAL MASS=F10.4)
 51 FORMAT(32H (ROLL-RADIUS OF GYRATION/L)**2=E14.6)
 52 FORMAT(33H (PITCH-RADIUS OF GYRATION/L)**2=E14.6)
 53 FORMAT(31H (YAW-RADIUS OF GYRATION/L)**2=E14.6)
 54 FORMAT(39H CENTRIFUGAL MOMENT YAW-ROLL/MASS/L**2=E14.6)
 55 FORMAT(/27H DISPLACED VOLUME/(L/2)**3=E14.6)
 56 FORMAT(38H LONGITUDINAL CENTER OF BOYANCY/(L/2)=E14.6)
 57 FORMAT(30H VERTICAL CENTER OF BOYANCY/L=E14.6)
 58 FORMAT(37H METACENTER HEIGHT OVER WATE-PLANE/L=E14.6)
 59 FORMAT(35H HEAVE-HEAVE RESTORING COEFFICIENT=E14.6)
 60 FORMAT(35H HEAVE-PITCH RESTORING COEFFICIENT=E14.6)
 61 FORMAT(35H PITCH-PITCH RESTORING COEFFICIENT=E14.6)
 62 FORMAT(61H DISTANCE OF CENTER OF GRAVITY FROM THE FORWARD MOST STA
   1TION=E14.6)
 63 FORMAT(26H Z-COORDINATE OF THE C.G.=E14.6)
900 FORMAT (51H0                              ADDITIONAL INPUT DATA)
910 FORMAT(4HOIT=I6,8X,7H IXAST=I6)
930 FORMAT(48HOSECTIONAL MASS AND MASS DISTRIBUTION INPUT DATA)
940 FORMAT(26H XMAS FOR EACH MASS POINT-)
950 FORMAT(26H YMAS FOR EACH MASS POINT-)
960 FORMAT(26H ZMAS FOR EACH MASS POINT-)
970 FORMAT(25H RRG FOR EACH MASS POINT-)
8000  FORMAT (*  STATION SPACING-*)
8010  FORMAT (9E14.6)
C
C  OUTPUT
C
      IF (PRNTOP .EQ. MIN) GO TO 2000
      WRITE (6,299) TITO
      WRITE(6,300)
      WRITE(6,301)
      WRITE(6,300)
      WRITE(6,302)
      WRITE(6,303)
      WRITE(6,304)
      WRITE(6,300)
      WRITE(6,305)
      WRITE(6,306)
      WRITE(6,307)
      WRITE(6,308)
      WRITE(6,309)
      WRITE(6,310)
      WRITE(6,311)
      WRITE(6,300)
      WRITE(6,312)
      WRITE(6,313)
      WRITE(6,314)
```

```
      WRITE(6,315)
      WRITE(6,316)
      WRITE(6,300)
      WRITE(6,317)
      WRITE(6,318)
      WRITE(6,319)
      WRITE(6,320)
      WRITE(6,321)
      WRITE(6,300)
      WRITE(6,322)
      WRITE(6,323)
      WRITE(6,300)
       WRITE (6,431) WORD,WORD2,WORD3
      WRITE(6,324)
      WRITE(6,300)
       NOS2 = NOS + 2
      WRITE(6,33) NOS2
      WRITE(6,36)
      NOSHAL=NOS
      NOSHIL=NOSHAL+2
      WRITE(6,2)(ST1(K),K=1,NOSHIL)
      WRITE(6,37)
      WRITE(6,2) (DS(K),K=1,NOSHAL)
      WRITE(6,39) NUT
      WRITE(6,40)
      DO 41 K=1,NOSHAL
      IK=K+1
      WRITE(6,42)(ST1(IK))
      WRITE(6,43) (X(K,J),J=1,NUT)
      WRITE(6,44) (Y(K,J),J=1,NUT)
   41 CONTINUE
      IF(IT) 73,74,73
   74 CONTINUE
      WRITE(6,45) NMAS
      WRITE(6,46)
      WRITE(6,2) (PMAS(I),I=1,NMAS)
      WRITE(6,47)
      WRITE(6,43) (XMAS(I),I=1,NMAS)
      WRITE(6,48) (ZMAS(I),I=1,NMAS)
   73 CONTINUE
      WRITE(6,31)ELL
      WRITE(6,325) BEAM
      WRITE(6,55) TVOL
      WRITE(6,56) TPST
      WRITE(6,57) CBV
      WRITE(6,58) CMC
      WRITE(6,59) RF33
      WRITE(6,60) RM35
      WRITE(6,61) RM55
      WRITE(6,62) XG
      WRITE(6,63) ZG
      WRITE(6,50) TMAS
      WRITE(6,51) EI44
      WRITE(6,52) EI55
      WRITE(6,53) EI66
      WRITE(6,54) EI46
      WRITE(6,900)
      WRITE(6,910) IT,IXAST
      IF(IT) 1000,920,1000
  920 WRITE(6,930)
      WRITE(6,940)
      DO 20 I=1,NMAS
      XMAS1(I)=XMAS(I)+XG
   20 CONTINUE
      WRITE(6,2)(XMAS1(I),I=1,NMAS)
      WRITE(6,950)
```

```
      WRITE(6,2)(YMAS(I),I=1,NMAS)
      WRITE(6,960)
      WRITE(6,2)(ZMAS(I),I=1,NMAS)
      WRITE(6,970)
      WRITE(6,2)(RRG(I),I=1,NMAS)
 1000 CONTINUE
      WRITE(6,10) NOH
      WRITE(6,11)(HDG1(JJ),JJ=1,NOH)
      WRITE(6,12)  NOB
      WRITE(6,13)  (FN(JJ),JJ=1,NOB)
      WRITE(6,14)  NWSTP
      WRITE(6,15)(INWSTP(JJ),JJ=1,NWSTP)
      WRITE(6,16)  NOK
      WRITE(6,17)  (BAM(LL),LL=1,NOK)
      WRITE(6,9003)
 9003 FORMAT(29H1ADDITIONAL INPUT INFORMATION)
      WRITE(6,591) IEND
  591 FORMAT(6H0IEND=I6)
      WRITE(6,592) IBILGE
  592 FORMAT(8H IBILGE=I6)
      WRITE(6,594) VNY,GRAV,AMODL,MOD
  594 FORMAT(5H VNY=F10.8,2X,6H GRAV=F10.4,2X,7H AMODL=F10.4,5H MOD=I6)
      WRITE(6,595)
  595 FORMAT(8H0ITS(K)=)
      WRITE(6,6)(ITS(K),K=1,NOS)
    6 FORMAT(16I5)
      WRITE(6,596)
  596 FORMAT(7H0RD(K)=)
      WRITE(6,8001)(RD(K),K=1,NOS)
 8001 FORMAT(8F10.4)
      GO TO (651,650),IBILGE
  651 WRITE(6,597) AKEELL,BEAMKL
  597 FORMAT(8H0AKEELL=F10.4,2X,8H BEAMKL=F10.4)
      WRITE(6,598)
  598 FORMAT(8H0RFD(K)=)
      WRITE(6,410)(RFD(K),K=1,NOS)
      WRITE(6,599)
  599 FORMAT(11H0DELTAD(K)=)
      WRITE(6,410)(DELTAD(K),K=1,NOS)
      WRITE(6,9001)
 9001 FORMAT(8H0RKD(K)=)
      WRITE(6,410)(RKD(K),K=1,NOS)
  410 FORMAT(12F10.4)
      WRITE(6,601)
  601 FORMAT(7H0SD(K)=)
      WRITE(6,410)(SD(K),K=1,NOS)
      WRITE(6,602)
  602 FORMAT(11H0COSPHD(K)=)
      WRITE(6,410)(COSPHD(K),K=1,NOS)
      WRITE(6,603)
  603 FORMAT(9H0PHID(K)=)
      WRITE(6,410)(PHID(K),K=1,NOS)
  650 CONTINUE
      GO TO (653,652),IPRES
  653 WRITE(6,604)
  604 FORMAT(9H0STPR(K)=)
      WRITE(6,8001)(STPR(K),K=1,NOS)
  652 CONTINUE
      WRITE(6,655)
  655 FORMAT(9H0THMD(K)=)
      WRITE(6,5060)(THMD(K),K=1,NHF)
 5060 FORMAT(12F10.4)
 2000  CONTINUE
       CALL SEPART (1)
       WRITE (1,8000)
       WRITE (1,8010)  (DS(K),K=1,NOS)
```

```
      WRITE(1,55) TVOL
      WRITE(1,56) TPST
      WRITE(1,57) CBV
      WRITE(1,58) CMC
      WRITE(1,59) RF33
      WRITE(1,60) RM35
      WRITE(1,61) RM55
      WRITE(1,62) XG
      WRITE(1,63) ZG
      WRITE(1,50) TMAS
      WRITE(1,51) EI44
      WRITE(1,52) EI55
      WRITE(1,53) EI66
      WRITE(1,54) EI46
      RETURN
      END
C
C------VERSION 4  -  CDC 6700  - P R O 2  -  JUNE, 1972----------------
C
       OVERLAY (LINK2,2,0)
       PROGRAM PRO2
       CALL SPRG1
       CALL SPRG2
       END
C
C------VERSION 4  -  CDC 6700  - S P R G 1  -  JUNE, 1972--------------
C
      SUBROUTINE SPRG1
C
C PROGRAMMER- W. FRANK,NSRDC
C
      COMMON AM(27),NUT,NMAS,NOS,ST(25),DS(25),EL,ELL,X(25,8),Y(25,8),PM
     1AS(27),XMAS(27),ZMAS(27),RRG(27),XG,ZG,TMAS,EI44,EI55,EI66,EI46,TP
     2ST,RF33,RM35,RM55,DGM,DIP,K,N,TVOL,ALFA(40,11),BETA(40,11),HDG(10)
     3,FN(5),BAM(30),CDG(10),SDG(10),OMAX,OMIN,NFR,NOK,NOB,NOH,OMEN(40),
     4FR(7,6),XX(25,7),YY(25,7),DEL(25,7),SNE(25,7),CSE(25,7),EN1(25,7),
     5UN,OMEGA,ID,TITO(12),WORD,NON,IXAST,HDG1(10),IT,CBV,CMC,PRNTOP
      COMMON ST1(27),YMAS(27),BEAM,DRAFT,DMAX,IRR,ML,IEND,IBILGE,IPRES,
     2VNY,GRAV,AMODL,MOD,AKEELL,BEAMKL,ITS(25),RD(25),RFD(25),DELTAD(25)
     3,RKD(25),SD(25),COSPHD(25),PHID(25),STPR(25),THMD(50)
      COMMON NWSTP,INWSTP(12)
       COMMON /TEMP/ HDR(10),IK(27),DUM3(4963)
      MOM=NOS-1
      NIX=NOS-2
      TOP=6.283185
      NOSHAL=NOS
      DO 22 K=1,NOSHAL
      ST(K)=ST(K)/EL
      DO 20 J=1,NUT
      X(K,J)=X(K,J)/EL
      Y(K,J)=Y(K,J)/EL
   20 CONTINUE
      DS(K)=DS(K)/EL
   22 CONTINUE
      DO 110 JJ=1,NOH
      HDG(JJ)=180.0-HDG1(JJ)
  110 CONTINUE
      DO 168 JJ=1,NOH
      HDR(JJ)=0.017453293*HDG(JJ)
      SDG(JJ)=SIN(HDR(JJ))
  168 CDG(JJ)=COS(HDR(JJ))
C
C CALCULATION OF NON-DIMENSIONAL FREQUENCY RANGES
C
      OTMIN = 99999.
      OTMAX = 0.
```

```
      DO 6000 N=1,NOH
      DO 6000 M=1,NOB
      TERM = FN(M)*CDG(N)
      DO 6000 K=1,NOK
      FACT = 6.283185/BAM(K)
      OTEMP = ABS(SQRT(FACT) + FACT*TERM)
      IF (OTEMP .LT. OTMIN) OTMIN = OTEMP
 6000 IF (OTEMP .GT. OTMAX) OTMAX = OTEMP
      EPS = .0001
      SRLG = SQRT(ELL/GRAV)
      SRDG = SQRT(DMAX/GRAV)
      SRLD = SQRT(ELL/DMAX)
      WEMAX = OTMAX/SRLG
      FACT = WEMAX*SRDG
      IF (FACT .GE. 1.) GO TO 6010
C IRREGULAR FREQUENCIES DO NOT EXIST
      IRR = 1
      QMAX = OTMAX + EPS
      KFR = 10
      GO TO 6020
C IRREGULAR FREQUENCIES EXIST
 6010 IRR = 2
      BT = BEAM/DRAFT
      IF (BT .LE. 4.) CON = .35
      IF (BT .GT. 4.) CON = .60
      QMAX = (WEMAX*SRDG + CON)*SRLD
 6020 QMIN = OTMIN - EPS
      CRIT = .7*SRLD
      IF (QMIN .GE. CRIT) QMIN = CRIT - EPS
      IF (IRR .EQ. 2) KFR = (QMAX - QMIN)/(.05*SRLD) + .9999999
      KFR = MIN0(KFR,40)
      IF (NFR .LE. 0) NFR = KFR
      IF (OMIN .LE. 0. .OR. OMIN .GT. QMIN) OMIN = QMIN
      IF (OMAX .LE. 0. .OR. OMAX .LT. QMAX) OMAX = QMAX
      OMAX=OMAX*SQRT(0.5)
      OMIN=OMIN*SQRT(0.5)
      DO 18  N=1,NFR
      DO 18 L=1,11
      ALFA(N,L)=0.0
      BETA(N,L)=0.0
   18 CONTINUE
      DO 19 K=1,NOSHAL
      DO 21 J=1,NON
      XX(K,J)=.5*(X(K,J)+X(K,J+1))
      YY(K,J)=.5*(Y(K,J)+Y(K,J+1))
      XINT=X(K,J)-X(K,J+1)
      YINT=Y(K,J)-Y(K,J+1)
      DEL(K,J)=SQRT(XINT**2+YINT**2)
      SNE(K,J)=YINT/DEL(K,J)
   21 CSE(K,J)=XINT/DEL(K,J)
   19 CONTINUE
      IK(1)=1
      DO 15 K=2,MOM
   15 IK(K)=2
      IK(NOS)=3
      DO 35 K=1,NOS
      LIK=IK(K)
      GO TO(36,27,28),LIK
   36 CALL PQRT(ST(3),ST(1),ST(2),P,Q,R,T)
      DO 29 J=1,NON
   29 EN1(K,J)=(SNE(1,J)*(Q*XX(3,J)-P*XX(2,J)+R*XX(1,J))-CSE(1,J)*(Q*YY(
     13,J)-P*YY(2,J)+R*YY(1,J)))/T
      GO TO 35
   27 CALL PQRT(ST(K+1),ST(K),ST(K-1),P,Q,R,T)
      DO 30 J=1,NON
   30 EN1(K,J)=(SNE(K,J)*(Q*XX(K+1,J)-P*XX(K-1,J)+R*XX(K,J))-CSE(K,J)*(Q
```

```
     1*YY(K+1,J)-P*YY(K-1,J)+R*YY(K,J)))/T
      GO TO 35
   28 CALL PORT(ST(NIX),ST(NOS),ST(MOM),P,Q,R,T)
      DO 31 J=1,NON
   31 EN1(K,J)=(SNE(NOS,J)*(Q*XX(NIX,J)-P*XX(MOM,J)+R*XX(NOS,J))-CSE(NOS
     1,J)*(Q*YY(NIX,J)-P*YY(MOM,J)+R*YY(NOS,J)))/T
   35 CONTINUE
      DO 101 K=1,NOS
      DO 102 J=1,NON
      EN1(K,J)=EN1(K,J)/SQRT(1.+EN1(K,J)**2)
  102 CONTINUE
  101 CONTINUE
   77 RETURN
      END
C
C------VERSION 4  -  CDC 6700  - S P R G 2  -  JUNE, 1972---------------
C
      SUBROUTINE SPRG2
C
C PROGRAMMER- O. FALTINSEN,DNV
C
       INTEGER H
      COMMON AM(27),NUT,NMAS,NOS,ST(25),DS(25),EL,ELL,X(25,8),Y(25,8),PM
     1AS(27),XMAS(27),ZMAS(27),RRG(27),XG,ZG,TMAS,EI44,EI55,EI66,EI46,TP
     2ST,RF33,RM35,RM55,DGM,DIP,K,N,TVOL,ALFA(40,11),BETA(40,11),HDG(10)
     3,FN(5),BAM(30),CDG(10),SDG(10),OMAX,OMIN,NFR,NOK,NOB,NOH,OMEN(40),
     4FR(7,6),XX(25,7),YY(25,7),DEL(25,7),SNE(25,7),CSE(25,7),EN1(25,7),
     5UN,OMEGA,ID,TITO(12),WORD,NON,IXAST,HDG1(10),IT,CBV,CMC,PRNTOP
      COMMON ST1(27),YMAS(27),BEAM,DRAFT,DMAX,IRR,ML,IEND,IBILGE,IPRES,
     2VNY,GRAV,AMODL,MOD,AKEELL,BEAMKL,ITS(25),RO(25),RFO(25),DELTAD(25)
     2,RKD(25),SD(25),COSPHD(25),PHID(25),STPR(25),THMD(50)
      COMMON NWSTP,INWSTP(12)
       COMMON /TEMP/ BLOG(2,7,7),YLOG(2,7,7),PRA(7,6),PRV(7,6),
     2 DUM3(1116),AR1(42),AR2(42),AI2(40),AI3(40),C(40),WD(40),A(3360)
       DATA MIN /3HMIN/
      FM=1.
      VOL=TVOL
      NFM=NFR-1
      DOME=(OMAX-OMIN)/(NFR-1)
      OMEN(1)=OMIN
      DO 27  N=2,NFR
   27 OMEN(N)=OMEN(N-1) +DOME
      L1=1
      L2=1
       NUMB = (NUT-1)*6
       NELEM = NFR*NUMB*2
       REWIND 20
       DO 37 K=1,NOS
      CALL FINV
      DIP=ST(K)-TPST
      KI=0
       KM = - NUMB
      DO 53  N=1,NFR
      OMEGA=OMEN(N)
      UN=OMEGA**2
      CALL KERN
      GO TO(34,35),ID
   35 WRITE(6,14) K,N
   14 FORMAT(29H0      MATRIX IS SINGULAR, K= I2,6H, N = I2)
      GO TO 777
   34 CONTINUE
      IF(IRR-1) 311,54,311
  311 CONTINUE
C
C  IRR=1 MEANS NO INTERPOLATION BECAUSE OF IRREGULAR FREQUENCIES
C
```

```
      YK=Y(K,1)+0.0001
      IF(YK)  54,2222,2222
 2222 CONTINUE
      YKN=Y(K,NUT)
      DAFT=ABS(YKN)
      WDR=OMEGA*SQRT(DAFT)
      IF(WDR-0.7)  54,55,55
   54 CONTINUE
      DO 41 LK=1,10
      GO TO(70,70,70,70,70,70,71,72,73,74),LK
   70 CONTINUE
      L=LK
      M=LK
      GO TO 75
   71 CONTINUE
      L=5
      M=3
      GO TO 75
   72 CONTINUE
      L=2
      M=6
      GO TO 75
   73 CONTINUE
      L=2
      M=4
      GO TO 75
   74 CONTINUE
      L=6
      M=4
   75 CONTINUE
   42 DADS        =0.0
      DDDS        =0.0
      DO 43 J=1,NON
      DADS        =DADS        +DEL(K,J)*FR(J,L)*PRA(J,M)
   43 DDDS        =DDDS        +DEL(K,J)*FR(J,L)*PRV(J,M)
      DADS        =2.0*DADS
      DDDS        =2.0*DDDS
      ALFA(N,LK)=ALFA(N,LK)+DS(K)*DADS*FM
      BETA(N,LK)=BETA(N,LK)+DS(K)*DDDS*FM
   41 CONTINUE
      GO TO 76
   55 CONTINUE
      KI=KI+1
      WD(KI)=WDR
      AI2(KI)=0.0
      AI3(KI)=0.0
      DO 52  J=1,NON
      AI2(KI)=AI2(KI)+DEL(K,J)*FR(J,2)*PRA(J,2)
      AI3(KI)=AI3(KI)+DEL(K,J)*FR(J,3)*PRA(J,3)
   52 CONTINUE
      FC1=2./DAFT/DAFT/UN/1.57
      AI2(KI)=AI2(KI)*FC1
      AI3(KI)=AI3(KI)*FC1
   76 CONTINUE
       KM = KM + NUMB
      DO 220  J=1,NON
      DO 220  M=1,6
       KM = KM + 1
       A(KM) = PRA(J,M)
       A(KM+NUMB) = PRV(J,M)
  220 CONTINUE
      NON=NUT-1
      NUMB=6*NON
   53 CONTINUE
C
C  INTERPOLATION  BECAUSE OF IRREGULAR FREQUENCIES
```

```
C
C  FIRST WE WRITE OUT FROM THE DRUM ALL PRESSURES FROM OMEGA*SQRT(DAFT/
C  GRAV)=0.7
      IF(KI-2) 32,32,77
   77 CONTINUE
      KID=NFR-KI
      DO 78 N12=1,NFR
       ITEMP = N12
      FAC=OMEN(N12)*SQRT(DAFT)
      IF(FAC-0.7) 78,79,79
   78 CONTINUE
   79 CONTINUE
       N12 = ITEMP
      NUMB=6*NON
       NSKIP = 2*(N12-1)*NUMB
       NDO = 2*(NFR-N12+1)
      C(NFR)=-1.
      C(KID+1)=-1.
      KIM=KI-1
      DO 21 N=2,KIM
      NN=KID+N
      AL1=AI2(N+1)-AI2(N)
      AL2=AI2(N+1)-AI2(N-1)
      AL3=AI2(N)-AI2(N-1)
      CL1=WD(N+1)-WD(N)
      CL2=WD(N+1)-WD(N-1)
      CL3=WD(N)-WD(N-1)
      C(NN)=(AL1**2+CL1**2+AL3**2+CL3**2-AL2**2-CL2**2)/2./SQRT(AL1**2+C
     1L1**2)/SQRT(AL3**2+CL3**2)
   21 CONTINUE
      DO 320  N13=1,NFR
       ITEMP = N13
      FAC=OMEN(N13)*SQRT(DAFT)
      IF(FAC-0.95)  320,321,321
  320 CONTINUE
  321 CONTINUE
       N13 = ITEMP
      DO 322  N=1,N13
      C(N)=-1.0
  322 CONTINUE
      DO 811 N=2,NFM
      IF(C(N)-(-0.5)) 811,811,24
   24 NV=IFIX(0.3/DOME/SQRT(DAFT))
      IF(NV) 9998,9998,9999
 9998 NV=1
 9999 CONTINUE
      KN=N-NV
      IF(KN-1) 531,532,532
  531 KN=1
  532 CONTINUE
      KS=N+NV
      ISUM=0
 4301 CONTINUE
      KS=KS+ISUM
      IF(KS-NFR) 431,431,432
  432 KS=NFR
  431 CONTINUE
      JR=KS+IFIX(0.1/DOME/SQRT(DAFT))
      IF(JR-NFR)  4303,4303,4302
 4302 JR=NFR
 4303 CONTINUE
      DO 4305 JM=KS,JR
      IF(C(JM)-(-0.5)) 4305,4306,4306
 4305 CONTINUE
      GO TO 4307
 4306 ISUM=NV
```

```
      IF(JR-NFR) 4308,4307,4307
 4308 GO TO 4301
 4307 CONTINUE
      DNO=FLOAT(KS-KN)
      DO 350 IR=1,2
      DO 350 J=1,NON
      DO 350 M=2,6,2
      NU1=(KN-N12)*NUMB*2+(IR-1)*NON*6+(J-1)*6+M
      NU2=(KS-N12)*NUMB*2+(IR-1)*NON*6+(J-1)*6+M
       NU1 = NU1 + NSKIP
       NU2 = NU2 + NSKIP
      DELT1=A(NU2)-A(NU1)
      DO 350 JK=KN,KS
      NU=(JK-N12)*NUMB*2+(IR-1)*NON*6+(J-1)*6+M
       NU = NU + NSKIP
      A(NU)=A(NU1)+DELT1*(JK-KN)/DNO
      C(JK)=-1.
  350 CONTINUE
  811 CONTINUE
      DO 121 N=2,KIM
      NN=KID+N
      AL1=AI3(N+1)-AI3(N)
      AL2=AI3(N+1)-AI3(N-1)
      AL3=AI3(N)-AI3(N-1)
      CL1=WD(N+1)-WD(N)
      CL2=WD(N+1)-WD(N-1)
      CL3=WD(N)-WD(N-1)
      C(NN)=(AL1**2+CL1**2+AL3**2+CL3**2-AL2**2-CL2**2)/2./SQRT(AL1**2+C
     1L1**2)/SQRT(AL3**2+CL3**2)
  121 CONTINUE
      DO 323  N=1,N13
      C(N)=-1.0
  323 CONTINUE
      DO 821 N=2,NFM
      IF(C(N)-(-0.5))  821,821,124
  124 NV=IFIX(0.3/DOME/SQRT(DAFT))
      IF(NV) 9996,9996,9997
 9996 NV=1
 9997 CONTINUE
      KN=N-NV
      IF(KN-1) 511,512,512
  511 KN=1
  512 CONTINUE
      KS=N+NV
      ISUM=0
 4311 CONTINUE
      KS=KS+ISUM
      IF(KS-NFR)  411,411,412
  412 KS=NFR
  411 CONTINUE
      JR=KS+IFIX(0.1/DOME/SQRT(DAFT))
      IF(JR-NFR) 4313,4313,4312
 4312 JR=NFR
 4313 CONTINUE
      DO 4315 JM=KS,JR
      IF(C(JM)-(-0.5)) 4315,4316,4316
 4315 CONTINUE
      GO TO 4317
 4316 ISUM=NV
      IF(JR-NFR) 4318,4317,4317
 4318 GO TO 4311
 4317 CONTINUE
      DNO=FLOAT(KS-KN)
      DO 351  IR=1,2
      DO 351  J=1,NON
      DO 351  M=1,5,2
```

```
      NU1=(KN-N12)*NUMB*2+(IR-1)*NON*6+(J-1)*6+M
      NU2=(KS-N12)*NUMB*2+(IR-1)*NON*6+(J-1)*6+M
       NU1 = NU1 + NSKIP
       NU2 = NU2 + NSKIP
      DELT1=A(NU2)-A(NU1)
      DO 351 JK=KN,KS
      NU=(JK-N12)*NUMB*2+(IR-1)*NON*6+(J-1)*6+M
       NU = NU + NSKIP
      A(NU)=A(NU1)+DELT1*(JK-KN)/DNO
      C(JK)=-1.
  351 CONTINUE
  821 CONTINUE
C
C  WE HAVE NOW ADJUSTED IF NECESSARY THE PRESSURES FROM  OMEGA*SQRT(DAFT
C     /GRAV)=0.7,AND ARE NOW GOING TO CALCULATE THE CORRESPONDING ADDED
C     MASS AND DAMPING
C
      DO 58 N=N12,NFR
      DO 58 LK=1,10
      GO TO(80,80,80,80,80,80,81,82,83,84),LK
   80 CONTINUE
      L=LK
      M=LK
      GO TO 85
   81 CONTINUE
      L=5
      M=3
      GO TO 85
   82 CONTINUE
      L=2
      M=6
      GO TO 85
   83 CONTINUE
      L=2
      M=4
      GO TO 85
   84 CONTINUE
      L=6
      M=4
   85 CONTINUE
      DADS=0.0
      DDDS=0.0
      DO 60 J=1,NON
      NU1=(N-N12)*NUMB*2+((J-1)*6+M)
      NU2=(N-N12)*NUMB*2+        NON*6+(J-1)*6+M
       NU1 = NU1 + NSKIP
       NU2 = NU2 + NSKIP
      DADS=DADS+DEL(K,J)*FR(J,L)*A(NU1)
   60 DDDS=DDDS+DEL(K,J)*FR(J,L)*A(NU2)
      DADS=2.0*DADS
      DDDS=2.0*DDDS
      ALFA(N,LK)=ALFA(N,LK)+DS(K)*DADS*FM
      BETA(N,LK)=BETA(N,LK)+DS(K)*DDDS*FM
   58 CONTINUE
   32 CONTINUE
        WRITE (20)  (A(I),I=1,NELEM)
   37   CONTINUE
        ENDFILE 20
        REWIND 20
      DO 33 N=1,NFR
      OMEGA=OMEN(N)
      UN=OMEGA**2
      DO 44 L=1,10
      ALFA(N,L)=ALFA(N,L)/VOL/UN
      BETA(N,L)=BETA(N,L)/VOL/OMEGA*1.4142136
   44 CONTINUE
```

```
      DO 45 L=4,6
      ALFA(N,L)=ALFA(N,L)*0.5*0.5
      BETA(N,L)=BETA(N,L)*0.5*0.5
   45 CONTINUE
      DO 46 L=7,10
      ALFA(N,L)=ALFA(N,L)*0.5
      BETA(N,L)=BETA(N,L)*0.5
   46 CONTINUE
      ALFA(N,10)=0.5*ALFA(N,10)
      BETA(N,10)=0.5*BETA(N,10)
   33 CONTINUE
C PRINT ZERO SPEED NON-DIMENSIONAL ADDED MASS AND DAMPING COEFFICIENTS
        CALL SEPART (1)
        DO 2300 JH=1,2
         IF (JH .EQ. 1) H = 1
         IF (JH .EQ. 2) H = 6
         IF (H .EQ. 6 .AND. PRNTOP .EQ. MIN) GO TO 2300
       WRITE (H,300) NFR
       WRITE (H,400) IRR
       WRITE(H,2235)
       WRITE(H,2224)
       DO 2225 N=1,NFR
       GXI=OMEN(N)*SQRT(2.)
       WRITE(H,2226)  GXI,ALFA(N,1),ALFA(N,2),ALFA(N,3), ALFA(N,4),ALFA(N
      1,5),ALFA(N,6),ALFA(N,7),ALFA(N,8),ALFA(N,9),ALFA(N,10)
 2225 CONTINUE
       WRITE(H,2227)
       WRITE(H,2228)
       DO  2229 N=1,NFR
       GXI=OMEN(N)*SQRT(2.)
       WRITE(H,2226) GXI,BETA(N,1),BETA(N,2),BETA(N,3),BETA(N,4),BETA(N,5
      1),BETA(N,6),BETA(N,7),BETA(N,8),BETA(N,9),BETA(N,10)
 2229 CONTINUE
  300 FORMAT(107H1NON-DIMENSIONAL, SPEED INDEPENDENT ADDED MASS AND DAMP
     1ING COEFFICIENTS FOR THE SPECIFIED FREQUENCIES (NFR=,I3,2H).)
  400 FORMAT(5H0IRR=I2,2H .,4X,104H IF IRR=2 INTERPOLATION OF IRREGULAR
     1FREQUENCIES IS PERFORMED.  IF IRR=1 INTERPOLATION IS NOT PERFORMED
     2.)
 2235 FORMAT(/45H NON-DIMENSIONALIZED ADDED MASS COEFFICIENTS-)
 2224 FORMAT(3X,6HWE(ND),5X,6HA(1,1),6X,6HA(2,2),6X,6HA(3,3),6X,6HA(4,4)
     2,6X,6HA(5,5),6X,6HA(6,6),6X,6HA(3,5),6X,6HA(2,6),6X,6HA(2,4),6X,
     26HA(4,6))
 2226 FORMAT(3X,F6.3,1P10E12.4)
 2227 FORMAT(/42H NON-DIMENSIONALIZED DAMPING COEFFICIENTS-)
 2228 FORMAT(3X,6HWE(ND),5X,6HB(1,1),6X,6HB(2,2),6X,6HB(3,3),6X,6HB(4,4)
     2,6X,6HB(5,5),6X,6HB(6,6),6X,6HB(3,5),6X,6HB(2,6),6X,6HB(2,4),6X,
     26HB(4,6))
 2300  CONTINUE
        CALL SEPART (2)
  777 RETURN
      END
C
C------VERSION 4  -  CDC 6700  - P O R T  -  JUNE, 1972----------------
C
      SUBROUTINE  PORT(A,B,C,P,Q,R,T)
      P=(A-B)/(B-C)
      Q=1.0/P
      R=P-Q
      T=A-C
      RETURN
      END
C
C------VERSION 4  -  CDC 6700  - F I N V  -  JUNE, 1972----------------
C
      SUBROUTINE  FINV
C
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C PROGRAMMER- W. FRANK,NSRDC
C
      COMMON AM(27),NUT,NMAS,NOS,ST(25),DS(25),EL,ELL,X(25,8),Y(25,8),PM
     1AS(27),XMAS(27),ZMAS(27),RRG(27),XG,ZG,TMAS,EI44,EI55,EI66,FI46,TP
     2ST,RF33,RM35,RM55,DGM,DIP,K,N,TVOL,ALFA(40,11),BETA(40,11),HDG(10)
     3,FN(5),BAM(30),CDG(10),SDG(10),OMAX,OMIN,NFR,NOK,NOR,NOH,OMEN(40),
     4FR(7,6),XX(25,7),YY(25,7),DEL(25,7),SNE(25,7),CSE(25,7),EN1(25,7),
     5UN,OMEGA,ID,TITO(12),WORD,NON,IXAST,HDG1(10),IT,CBV,CMC,PRNTOP
      COMMON ST1(27),YMAS(27),BEAM,DRAFT,DMAX,IPR,ML,IEND,IBILCE,IPRES,
     2VNY,GRAV,AMODL,MOD,AKEELL,BEAMKL,ITS(25),RD(25),RFD(25),DELTAD(25)
     2,RKD(25),SD(25),COSPHD(25),PHID(25),STPR(25),THMD(50)
      COMMON NWSTP,INWSTP(12)
       COMMON /TEMP/ BLOG(2,7,7),YLOG(2,7,7),DUM3(4804)
      DO 10 I=1,NON
      XM2=XX(K,I)-X(K,1)
      YM2=YY(K,I)-Y(K,1)
      XP2=XX(K,I)+X(K,1)
      YP2=YY(K,I)+Y(K,1)
      FPR2=.5*ALOG(XM2**2+YM2**2)
      FPL2=.5*ALOG(XP2**2+YM2**2)
      FCR2=.5*ALOG(XM2**2+YP2**2)
      FCL2=.5*ALOG(XP2**2+YP2**2)
      APR2=ATAN2(YM2,XM2)
      APL2=ATAN2(YM2,XP2)
      ACR2=ATAN2(YP2,XM2)
      ACL2=ATAN2(YP2,XP2)
      DO 10 J=1,NON
      XM1=XX(K,I)-X(K,J+1)
      YM1=YY(K,I)-Y(K,J+1)
      XP1=XX(K,I)+X(K,J+1)
      YP1=YY(K,I)+Y(K,J+1)
      FPR1=.5*ALOG(XM1**2+YM1**2)
      FPL1=.5*ALOG(XP1**2+YM1**2)
      FCR1=.5*ALOG(XM1**2+YP1**2)
      FCL1=.5*ALOG(XP1**2+YP1**2)
      APR1=ATAN2(YM1,XM1)
      APL1=ATAN2(YM1,XP1)
      ACR1=ATAN2(YP1,XM1)
      ACL1=ATAN2(YP1,XP1)
      SIMJ=SNE(K,I)*CSE(K,J)-SNE(K,J)*CSE(K,I)
      CIMJ=CSE(K,I)*CSE(K,J)+SNE(K,I)*SNE(K,J)
      SIPJ=SNE(K,I)*CSE(K,J)+SNE(K,J)*CSE(K,I)
      CIPJ=CSE(K,I)*CSE(K,J)-SNE(K,I)*SNE(K,J)
      DPNR=SIMJ*(FPR1-FPR2)+CIMJ*(APR1-APR2)
      PPR=CSE(K,J)*(XM1*FPR1-YM1*APR1-XM1-XM2*FPR2+YM2*APR2+XM2)+SNE(K,J
     1)*(YM1*FPR1+XM1*APR1-YM1-YM2*FPR2-XM2*APR2+YM2)
      DPNL=SIPJ*(FPL2-FPL1)+CIPJ*(APL2-APL1)
      PPL=CSE(K,J)*(XP2*FPL2-YM2*APL2-XP2-XP1*FPL1+YM1*APL1+XP1)+SNE(K,J
     1)*(YM1*FPL1+XP1*APL1+YM2-YM2*FPL2-XP2*APL2-YM1)
      DCNR=SIPJ*(FCR1-FCR2)+CIPJ*(ACR1-ACR2)
      PCR=CSE(K,J)*(XM1*FCR1-YP1*ACR1-XM1-XM2*FCR2+YP2*ACR2+XM2)+SNE(K,J
     1)*(YP2*FCR2+XM2*ACR2+YP1-YP1*FCR1-XM1*ACR1-YP2)
      DCNL=SIMJ*(FCL2-FCL1)+CIMJ*(ACL2-ACL1)
      PCL=CSE(K,J)*(XP2*FCL2-YP2*ACL2-XP2-XP1*FCL1+YP1*ACL1+XP1)+SNE(K,J
     1)*(YP2*FCL2+XP2*ACL2-YP2-YP1*FCL1-XP1*ACL1+YP1)
      BLOG(1,I,J)=DPNR+DPNL-DCNR-DCNL
      YLOG(1,I,J)=PPR+PPL-PCR-PCL
      BLOG(2,I,J)=DPNR-DPNL-DCNR+DCNL
      YLOG(2,I,J)=PPR-PPL-PCR+PCL
      IF(J-NON) 475,10,10
  475 XM2=XM1
      YM2=YM1
      XP2=XP1
      YP2=YP1
      FPR2=FPR1
      FPL2=FPL1
```

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      FCR2=FCR1
      FCL2=FCL1
      APR2=APR1
      APL2=APL1
      ACR2=ACR1
      ACL2=ACL1
   10 CONTINUE
      RETURN
      END
C
C------VERSION 4  -  CDC 6700  - K E R N  -  JUNE, 1972-----------------
C
      SUBROUTINE KERN
C
C PROGRAMMER- W. FRANK,NSRDC
C
      COMMON AM(27),NUT,NMAS,NOS,ST(25),DS(25),EL,ELL,X(25,8),Y(25,8),PM
     1AS(27),XMAS(27),ZMAS(27),RRG(27),XG,ZG,TMAS,EI44,EI55,EI66,EI46,TP
     2ST,RF33,RM35,RM55,OGM,DIP,K,N,TVOL,ALFA(40,11),BETA(40,11),HDG(10)
     3,FN(5),BAM(30),CDG(10),SDG(10),OMAX,OMIN,NFR,NOK,NOR,NOH,OMEN(40),
     4FR(7,6),XX(25,7),YY(25,7),DEL(25,7),SNE(25,7),CSE(25,7),EN1(25,7),
     5UN,OMEGA,ID,TITO(12),WORD,NON,IXAST,HDG1(10),IT,CHV,CMC,PRNTOP
      COMMON ST1(27),YMAS(27),BEAM,DRAFT,DMAX,IRR,ML,IEND,IBILGE,IPRES,
     2VNY,GRAV,AMODL,MOD,AKEELL,BEAMKL,ITS(25),RD(25),RFD(25),DELTAD(25)
     2,RKD(25),SD(25),COSPHD(25),PHID(25),STPP(25),THMD(50)
      COMMON NWSTP,INWSTP(12)
       COMMON /TEMP/ BLOG(2,7,7),YLOG(2,7,7),PRA(7,6),PRV(7,6),
     2 CON1(14,2),CON2(14,2),CT1(14,14),CT2(14,14),SOUR1(7,7),
     2 SOUR2(7,7),WAVE1(7,7),WAVE2(7,7),INDEX(14,3),DUM3(4034)
      NOE=2*NON
      DO 1 I=1,NON
      NI=NON+I
      FR(I,1)=EN1(K,I)
      FR(I,2)=-SNE(K,I)
      FR(I,3)=CSE(K,I)
      FR(I,4)=XX(K,I)*CSE(K,I)-YY(K,I)*FR(I,2)
      FR(I,5)=-DIP*FR(I,3)
      FR(I,6)=DIP*FR(I,2)
      CON1(I,1)=0.0
      CON1(I,2)=0.0
      CON2(I,1)=0.0
      CON2(I,2)=0.0
      CON1(NI,1)=OMEGA*FR(I,1)
      CON1(NI,2)=OMEGA*FR(I,3)
      CON2(NI,1)=OMEGA*FR(I,2)
      CON2(NI,2)=OMEGA*FR(I,4)
      XR2=UN*(XX(K,I)-X(K,1))
      YR2=-UN*(YY(K,I)+Y(K,1))
      XL2=UN*(XX(K,I)+X(K,1))
      YL2=YR2
      CALL DAVID(XR2,YR2,EJ2,CXR2,SXR2,RAR2,RBR2,CR2,SR2)
      CALL DAVID(XL2,YL2,EJ2,CXL2,SXL2,RAL2,RBL2,CL2,SL2)
      DO 1  J=1,NON
      NJ=NON+J
      SIPJ=SNE(K,I)*CSE(K,J)+SNE(K,J)*CSE(K,I)
      CIPJ=CSE(K,I)*CSE(K,J)-SNE(K,I)*SNE(K,J)
      SIMJ=SNE(K,I)*CSE(K,J)-SNE(K,J)*CSE(K,I)
      CIMJ=CSE(K,I)*CSE(K,J)+SNE(K,I)*SNE(K,J)
      XR1=UN*(XX(K,I)-X(K,J+1))
      YR1=-UN*(YY(K,I)+Y(K,J+1))
      XL1=UN*(XX(K,I)+X(K,J+1))
      YL1=YR1
      CALL DAVID(XR1,YR1,EJ1,CXR1,SXR1,RAR1,RBR1,CR1,SR1)
      CALL DAVID(XL1,YL1,EJ1,CXL1,SXL1,RAL1,RBL1,CL1,SL1)
      DPR=2.*(SIPJ*(CR1-CR2)-CIPJ*(SR1-SR2))
      DPL=2.*(CIMJ*(SL1-SL2)-SIMJ*(CL1-CL2))
```

```
      PPR=2./UN*(SNE(K,J)*(RAR1-RAR2)+CSE(K,J)*(RBR1-RBR2))
      PPL=2./UN*(SNE(K,J)*(RAL1-RAL2)+CSE(K,J)*(RBL2-RBL1))
      DWR=6.2831853*(EJ2*(SXR2*CIPJ-CXR2*SIPJ)-EJ1*(SXR1*CIPJ-CXR1*SIPJ)
     1)
      DWL=6.2831853*(EJ1*(SXL1*CIMJ-CXL1*SIMJ)-EJ2*(SXL2*CIMJ-CXL2*SIMJ)
     1)
      PWR=6.2831853/UN*(EJ1*(SXR1*CSE(K,J)-CXR1*SNE(K,J))-EJ2*(SXR2*CSE(
     1K,J)-CXR2*SNE(K,J)))
      PWL=6.2831853/UN*(EJ2*(SXL2*CSE(K,J)+CXL2*SNE(K,J))-EJ1*(SXL1*CSE(
     1K,J)+CXL1*SNE(K,J)))
      CT1(I,J)=BLOG(1,I,J)+DPR+DPL
      CT2(I,J)=BLOG(2,I,J)+DPR-DPL
      CT1(NI,NJ)=CT1(I,J)
      CT2(NI,NJ)=CT2(I,J)
      CT1(I,NJ)=DWR+DWL
      CT2(I,NJ)=DWR-DWL
      CT1(NI,J)=-CT1(I,NJ)
      CT2(NI,J)=-CT2(I,NJ)
      SOUR1(I,J)=YLOG(1,I,J)+PPR+PPL
      SOUR2(I,J)=YLOG(2,I,J)+PPR-PPL
      WAVE1(I,J)=PWR+PWL
      WAVE2(I,J)=PWR-PWL
      IF(J-NON) 2,1,1
    2 XR2=XR1
      YR2=YR1
      CXR2=CXR1
      SXR2=SXR1
      RAR2=RAR1
      RBR2=RBR1
      CR2=CR1
      SR2=SR1
      XL2=XL1
      YL2=YL1
      EJ2=EJ1
      CXL2=CXL1
      SXL2=SXL1
      RAL2=RAL1
      RBL2=RBL1
      CL2=CL1
      SL2=SL1
    1 CONTINUE
      CALL MATINS(CT1,14,NOE,CON1,2,2,DTE,ID,INDEX)
      GO TO(3,9),ID
    3 CALL MATINS(CT2,14,NOE,CON2,2,2,DTO,ID,INDEX)
      GO TO (4,9),ID
    4 DO 5 I=1,NON
      DO 6 L=1,4
      PRA(I,L)=0.0
    6 PRV(I,L)=0.0
      DO 7 J=1,NON
      NJ=NON+J
      PRA(I,1)=PRA(I,1)+CON1(J,1)*WAVE1(I,J)-CON1(NJ,1)*SOUR1(I,J)
      PRA(I,2)=PRA(I,2)+CON2(J,1)*WAVE2(I,J)-CON2(NJ,1)*SOUR2(I,J)
      PRA(I,3)=PRA(I,3)+CON1(J,2)*WAVE1(I,J)-CON1(NJ,2)*SOUR1(I,J)
      PRA(I,4)=PRA(I,4)+CON2(J,2)*WAVE2(I,J)-CON2(NJ,2)*SOUR2(I,J)
      PRV(I,1)=PRV(I,1)+CON1(J,1)*SOUR1(I,J)+CON1(NJ,1)*WAVE1(I,J)
      PRV(I,2)=PRV(I,2)+CON2(J,1)*SOUR2(I,J)+CON2(NJ,1)*WAVE2(I,J)
      PRV(I,3)=PRV(I,3)+CON1(J,2)*SOUR1(I,J)+CON1(NJ,2)*WAVE1(I,J)
    7 PRV(I,4)=PRV(I,4)+CON2(J,2)*SOUR2(I,J)+CON2(NJ,2)*WAVE2(I,J)
      DO 8 L=1,4
      PRA(I,L)=OMEGA*PRA(I,L)
    8 PRV(I,L)=OMEGA*PRV(I,L)
      PRA(I,5)=-DIP*PRA(I,3)
      PRA(I,6)=DIP*PRA(I,2)
      PRV(I,5)=-DIP*PRV(I,3)
    5 PRV(I,6)=DIP*PRV(I,2)
```

```
    9 RETURN
      END
C
C------VERSION 4  -  CDC 6700  - D A V I D  -  JUNE, 1972---------------
C
      SUBROUTINE DAVID(X,Y,E,C,S,RA,RB,CIN,SON)
C
C PROGRAMMER- W. FRANK,NSRDC, AND O. FALTINSEN,DNV
C
      AT=ATAN2(X,Y)
      ARG=AT-1.5707963
      E=EXP(-Y)
      C=COS(X)
      S=SIN(X)
      R=X**2+Y**2
      TEST=0.00001
      IF(R-1.0) 5,10,10
   10 TEST=0.1*TEST
      IF(R-2.0) 5,20,20
   20 TEST=0.1*TEST
      IF(R-4.0) 5,30,30
   30 TEST=0.1*TEST
      IF(R-200.0)  5,31,31
   31 TEST=0.0001
      AL=0.5*ALOG(R)
      Y=-Y
      SUMC=Y/SQRT(R)
      SUMS=X/SQRT(R)
      TC=SUMC
      TS=SUMS
      DO 33  K=1,15
      TO=TC
      TC=-(TC*Y-X*TS)*K/R
      TS=-(TS*Y+X*TO)*K/R
      SUMC=SUMC+TC
      SUMS=SUMS+TS
      IF(K-15)    34,35,35
   34 IF((ABS(TC)+ABS(TS))-TEST)          35,35,33
   35 SUMC=SUMC/SQRT(R)*(-1.)
      SUMS=SUMS/SQRT(R)*(-1.)
      SON=SUMS+3.141593*E*C
      SON=-SON
      CIN=SUMC+3.141593*E*S
      RA=AL-CIN
      RB=ARG+SON
      GO TO 4
   33 CONTINUE
    5 AL=0.5*ALOG(R)
      SUMC=0.57721566+AL+Y
      SUMS=AT+X
      TC=Y
      TS=X
      DO 1 K=1,500
      TO=TC
      COX=K
      CAY=K+1
      FACT=COX/CAY**2
      TC=FACT*(Y*TC-X*TS)
      TS=FACT*(Y*TS+X*TO)
   25 SUMC=SUMC+TC
      SUMS=SUMS+TS
      IF(K-500)  40,3,3
   40 IF((ABS(TC)+ABS(TS))-TEST) 3,3,1
    3 CIN=E*(C*SUMC+S*SUMS)
      SON=E*(S*SUMC-C*SUMS)
      RA=AL-CIN
```

```
      RB=ARG*SON
      GO TO 4
    1 CONTINUE
    4 RETURN
      END
C
C------VERSION 4   -   CDC 6700   - P R O 3   -   JUNE, 1972----------------
C
      OVERLAY (LINK3,3,0)
      PROGRAM PRO3
      DIMENSION GMU(6,6)
      CALL SPRG4 (GMU)
      CALL SPRG5 (GMU)
      END
C
C------VERSION 4   -   CDC 6700   - S P R G 4   -   JUNE, 1972--------------
C
      SUBROUTINE SPRG4(GMU)
C
C PROGRAMMER- O. FALTINSEN,DNV
C
      COMMON AM(27),NUT,NMAS,NOS,ST(25),DS(25),EL,ELL,X(25,8),Y(25,8),PM
     1AS(27),XMAS(27),ZMAS(27),RRG(27),XG,ZG,TMAS,EI44,EI55,EI66,EI46,TP
     2ST,RF33,RM35,RM55,DGM,DIP,K,N,TVOL,ALFA(40,11),BETA(40,11),HDG(10)
     3,FN(5),BAM(30),CDG(10),SDG(10),OMAX,OMIN,NFR,NOK,NOB,NOH,OMEN(40),
     4FR(7,6),XX(25,7),YY(25,7),DEL(25,7),SNE(25,7),CSE(25,7),EN1(25,7),
     5UN,OMEGA,ID,TITO(12),WORD,NON,IXAST,HDG1(10),IT,CBV,CMC,PRNTOP
      COMMON ST1(27),YMAS(27),BEAM,DRAFT,DMAX,IRR,ML,IEND,IBILGE,IPRES,
     2VNY,GRAV,AMODL,MOD,AKEELL,BEAMKL,ITS(25),RD(25),RFD(25),DELTAD(25)
     2,RKD(25),SD(25),COSPHD(25),PHID(25),STPR(25),THMD(50)
      COMMON NWSTP,INWSTP(12)
      DIMENSION GMU(6,6)
      DO 111 I=1,6
      DO 111 J=1,6
  111 GMU(I,J)=0.0
      GMU(1,1)=1.
      GMU(2,2)=1.
      GMU(3,3)=1.
      GMU(4,4)=EI44
      GMU(4,6)=EI46
      GMU(5,5)=EI55
      GMU(6,6)=EI66
      GMU(4,2)=-ZG/ELL
      GMU(2,4)=-ZG/ELL
      GMU(1,5)=ZG/ELL
      GMU(5,1)=ZG/ELL
      RETURN
      END
```

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C                                                                       SP5        2
C------VERSION 4  -  CDC 6700  - S P R G 5  -  JUNE, 1972--------------- SP5        3
C                                                                       SP5        4
      SUBROUTINE SPRG5(GMU)                                             SP5        5
C                                                                       SP5        6
C PROGRAMMER- W. FRANK,NSRDC, AND O. FALTINSEN,DNV                      SP5        7
C                                                                       SP5        8
      DIMENSION THCAL(30)                                               SP5        9
      COMMON AM(27),NUT,NMAS,NOS,ST(25),OS(25),EL,ELL,X(25,8),Y(25,8),PM SP5       10
     1AS(27),XMAS(27),ZMAS(27),RRG(27),XG,ZG,TMAS,EI44,EI55,EI66,EI46,TP SP5       11
     2ST,RF33,RM35,RM55,CGM,DIP,K,N,TVUL,ALFA(40,11),BETA(40,11),HOG(10) SP5       12
     3,FN(5),BAM(30),COG(10),SOG(10),OMAX,OMIN,NFR,NGK,NOB,NOH,OMEN(40), SP5       13
     4FR(7,6),XX(25,7),YY(25,7),DEL(25,7),SNE(25,7),CSE(25,7),EN1(25,7), SP5       14
     5UN,OMEGA,IO,TITO(12),WORD,NON,IXAST,HOG1(10),IT,LEV,CMC,PRNTOP     SP5       15
      COMMON ST1(27),YMAS(27),BEAM,DRAFT,DMAX,IRR,ML,IEND,IBILGE,IPRES,  SP5       16
     2VNY,GRAV,AMODL,MOD,AKEELL,BEAMKL,ITS(25),RD(25),RFD(25),DELTAD(25) SP5       17
     2,RKD(25),SD(25),CUSPFD(25),PHID(25),STPR(25),THMD(50)             SP5       18
      COMMON NWSTP,INWSTP(12)                                           SP5       19
       COMMON /LOOPRM/ STLD(24),WORD2,WORD3,IDAMP,IPRCNT,B2(5),B3(5),   SP5       20
     2 PB2(25,5),PB3(25,5),ICLASS                                       SP5       21
      COMMON /PFOIL/ IFOIL,RHO,NF,CPL(10),SPAN(10),CHORD(10),S(10),YF(10 FMOD      81
     2),ZF(10),DGAMMA(10),CLZ(10),ASP(10),IPRINT                        FMOD      82
      COMMON /QFOIL/ GA(6,6)                                            FMOD      83
       DIMENSION A(3360)                                                SP5       22
       INTEGER PRNTOP,H                                                 SP5       23
      COMPLEX CFAC(6),CSUM(6),DODD,DEVEN,DUM3,DUM2,CPET,PP,QQ,II        SP5       24
      COMPLEX DFX(6)                                                    SP5       25
      COMPLEX DEF(6)                                                    SP5       26
       COMMON /TEMP/ POFR(6,25),POFI(6,25),RMO(6,30),AIMO(6,30),        SP5       27
     2 DA1(11),DB1(11),PEXR(6,25),PEXI(6,25),DADS(10,26),DCDS(10,26),    SP5       28
     2 TOA(6,6),TOB(6,6),SRF33(27),SRM35(27),SRM55(27),SC44(27),        SP5       29
     2 PAV(25,7,6),PAA(25,7,6),DA(6,6),DB(6,6),TEV(6,6),BEV(6,1),       SP5       30
     2 TOD(6,6),BOD(6,1),INDEX(6,3),AR1(42),AR2(42),AT1(42),AT2(42),    SP5       31
     2 VC(25),SBKD(27),EDDY(27),RGB(27),PRERE(8,14),PREIM(8,14),        SP5       32
     2 FZRSG(25),BVRSG(25),BVISG(25),FZISG(25),FYRSG(25),FYISG(25),     SP5       33
     2 THRSG(25),THISG(25),BLRSG(25),BLISG(25),RHMD(50),WE(30),ZN(30),  SP5       34
     2 XL1LMD(30),IHMD(50),WAVAMP(30),DUM4(76)                         SP5       35
       COMMON /TMP1/ FACT,JJ,HUIG1,VKNOTS,WSLOPE,WSTP,IWSTP,LL,GXI      SP5       36
       COMMON /TMP2/ SHM(30,6,2)                                        SP5       37
       COMMON /TMP3/ RLO(5,30,25),AILO(5,30,25),STATN(24)               SP5       38
       COMMON /TMP4/ HMO(5,50,2),NHF,EPS                                SP5       39
       COMMON /TMP5/ BDV(30,6,2)                                        SP5       40
      DIMENSION GMU(6,6),TODF(6,6),TEVF(6,6),BODF(6),BEVF(6),T(32,62)   FMOD      84
      DIMENSION TODA(6,6),TEVA(6,6),BODA(6),BEVA(6),TODB(6,6),TEVB(6,6), FMOD      85
     2BODB(6),BEVB(6),TODC(6,6),TEVC(6,6),BODC(6),BEVC(6)               FMOD      86
       DATA MIN /3HMIN/                                                 SP5       42
      BACKSPACE 1                                                       FMOD      87
 2198 FORMAT(118H1NON-DIMENSIONAL ADDED MASS,DAMPING,AND RESTORING COEFF FMOD      88
     2ICIENTS AND EXCITING FORCES AND MOMENTS OF THE STRUTS AND FOILS)  FMOD      89
 2199 FORMAT(41X,12A6,15X,3H***///17X,9HHEADING =,F5.0,4H DEG,7X,12HSHIP FMOD      90
     2 SPEED =,F6.2,6H KNOTS/18X,16H(HEAD SEAS =180),9X,15HFROUDE NUMBER FMOD      91
     3 =,F7.4,///)                                                      FMOD      92
 2200 FORMAT(/58H NON-DIMENSIONALIZED ADDED MASS COEFFICIENTS OF THE FOI FMOD      93
     1LS-)                                                              FMOD      94
 2201 FORMAT(3X,6HWE(NO),5X,6HA(1,1),6X,6HA(2,2),6X,6HA(3,3),6X,6HA(4,4) FMOD      95
     1,6X,6HA(5,5),6X,6HA(6,6),6X,6HA(3,5),6X,6HA(2,6),6X,6HA(2,4),6X,6H FMOD      96
     2A(4,6))                                                           FMOD      97
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2202 FORMAT(3X,F6.3,1P10E12.4)                                          FMOD      98
2203 FORMAT(9X,1P10E12.4)                                               FMOD      99
2204 FORMAT(/55H NON-DIMENSIONALIZED DAMPING COEFFICIENTS OF THE FOILS- FMOD     100
    1)                                                                  FMOD     101
2205 FORMAT(3X,6HWE(NO),5X,6HB(1,1),6X,6HB(2,2),6X,6HB(3,3),6X,6HB(4,4) FMOD     102
    1,6X,6HB(5,5),6X,6HB(6,6),6X,6HB(3,5),6X,6HB(2,6),6X,6HB(2,4),6X,6H FMOD     103
    2B(4,6))                                                            FMOD     104
2206 FORMAT(/57H NON-DIMENSIONALIZED RESTORING COEFFICIENTS OF THE FOIL FMOD     105
    1S-)                                                                FMOD     106
2207 FORMAT(3X,6HWE(NO),5X,6HC(1,1),6X,6HC(2,2),6X,6HC(3,3),6X,6HC(4,4) FMOD     107
    1,6X,6HC(5,5),6X,6HC(6,6),6X,6HC(3,5),6X,6HC(2,6),6X,6HC(2,4),6X,6H FMOD     108
    2C(4,6))                                                            FMOD     109
2208 FORMAT(/,* NON-DIMENSIONALIZED FORCE AND MOMENT FUNCTIONS OF THE F FMOD     110
    1OILS-*)                                                            FMOD     111
2209 FORMAT(3X,6HWE(NO),4X,5HSURGE,6X,4HSWAY,7X,5HHEAVE,8X,4HROLL,7X,5H FMOD     112
    2PITCH,9X,3HYAW)                                                    FMOD     113
2210 FORMAT(3X,F6.3,1P6E12.4)                                           FMOD     114
2211 FORMAT(9X,1P6E12.4)                                                FMOD     115
8001 FORMAT(///51H  TOD*X=BOD  BEFORE INSERTION OF HYDROFOIL ELEMENTS/) FMOD     116
8011 FORMAT(///51H  TEV*X=BEV  BEFORE INSERTION OF HYDROFOIL ELEMENTS/) FMOD     117
8003 FORMAT(///50H  TOD*X=BOD  AFTER INSERTION OF HYDROFOIL ELEMENTS/)  FMOD     118
8013 FORMAT(///50H  TEV*X=BEV  AFTER INSERTION OF HYDROFOIL ELEMENTS/)  FMOD     119
8002 FORMAT(///*  MATRICIES TODF AND BODF*/)                            FMOD     120
8012 FORMAT(///*  MATRICIES TEVF AND BEVF*/)                            FMOD     121
8021 FORMAT(9X,1P6E12.3,7X,1HX,I2,7H   REAL,6X,1P1E12.3)                FMOD     122
8022 FORMAT(9X,1P6E12.3,7X,1HX,I2,7H   IMAG,6X,1P1E12.3)                FMOD     123
8004 FORMAT(///14H   X=INVTOD*BOD/)                                     FMOD     124
8014 FORMAT(///14H   X=INVTEV*BEV/)                                     FMOD     125
8023 FORMAT(9X,1P1E12.3,12X,1P6E12.3,12X,1P1E12.3)                      FMOD     126
C                                                                       SP5       43
C BY CALLING PREST THE RESTORING FORCES AND MOMENTS FOR THE VARIOUS SECT SP5      44
C OF THE SHIP ARE CALCULATED.                                           SP5       45
C     SRF33(K)=RESTORING COEFFICIENT(HEAVE-HEAVE) UP TO STATION K       SP5       46
C     SRF35(K)=RESTORING COEFFICIENT(HEAVE-PITCH) UP TO STATION K       SP5       47
C     SRF55(K)= RESTORING COEFFICIENT(PITCH-PITCH) UP TO STATION K      SP5       48
C     SG44(K)=METACENTRIC HEIGHT OVER THE WATERPLANE FOR THE PART OF THE SP5      49
C        UP TO STATION K                                                SP5       50
C  THESE VARIABLES ARE USED FOR THE CALCULATION OF LOADS.               SP5       51
C                                                                       SP5       52
      DO 687  K=1,NOS                                                   SP5       53
      CALL   PREST(PRF33,PRM35,PRM55,PC44)                              SP5       54
      SRF33(K)=PRF33                                                    SP5       55
      SRM35(K)=PRM35                                                    SP5       56
      SRM55(K)=PRM55                                                    SP5       57
      SG44(K)=PC44                                                      SP5       58
  687 CONTINUE                                                          SP5       59
      II=(0.,1.)                                                        SP5       60
      FACT=57.295779                                                    SP5       61
      PI=3.141593                                                       SP5       62
      C33=RF33                                                          SP5       63
      C35=RM35                                                          SP5       64
      C55=RM55                                                          SP5       65
      C44=DGM                                                           SP5       66
C                                                                       SP5       67
C      IPRES=1 WE WANT TO CALCULATE PRESSURE                            SP5       68
C      IPRES=2 WE DO NOT WANT TO CALCULATE PRESSURE                     SP5       69
C                                                                       SP5       70
```

```
C
C       IEND=1   ENDTERMS IN THE EQUATIONS OF MOTION
C       IEND=2   NO ENDTERMS IN THE EQUATIONS OF MOTION
C     IBILGE=1  MEANS THAT THE SHIP HAS BILGEKEEL
C     IBILGE=2  MEANS THAT THE SHIP HAS NOT BILGEKEEL
C
C
C     MOD=1 MEANS MODEL WITHOUT BILGEKEEL
C     MOD=2 THE OTHER CASES
C     THM IS A FIRST APPROXIMATION TO MEAN MAXIMUM ROLL-AMPLITUDE (RADIANS
C     VNY=KINEMATIC VISCOSITY
C     GRAV=ACCELERATION OF GRAVITY
C
C   AMODL= THE LENGTH OF THE MODEL FOR REYNOLDS NUMBER
C
C
C   KO(K)='BILGERADIUS' FOR STATION K
C
C
C   ITS(K)=1  FORESECTION   WHERE  KG/B#1.2
C   ITS(K)=2  MIDSECTION
C   ITS(K)=3  AFTSECTION     WHERE  B/KG#1.0
C   ITS(K)=4  OTHER CASES
C
C
C      EDDY(K)=COEFFICIENT OF EDDY MAKING DAMPING FOR STATION K
C
C   ML=1  CALCULATE MOTIONS
C      ML=2  CALCULATE MOTIONS AND  LOADS
C
C
C      SET STPR(K)=0.0 IF WE DO NOT WANT PRESSURE ON STATION K
C      SET STPR(K)=1.0 IF WE WANT PRESSURES ON STATION K
C      IT IS NOT POSSIBLE TO GET PRESSURES ON THE FIRST AND LAST STATION
C
       VNY=VNY/SQRT(GRAV*ELL**3)
       NOSHAL=NOS
       SGL = SQRT(GRAV/ELL)
       SLG = 1./SGL
       NHF = NOH*NOB*NHSTP
       KTH=0
C
C   THIS IS WHERE THE LOOPS FOR THE CALCULATION OF MOTIONS AND LOADS BEGI
C    THE OUTER LOOP IS FOR HEADING AND FROUDE NUMBER AND THE INNER LOOP I
C      WAVELENGTH.
C
       EPS = .017453293
       FCT = .75
       DO 599  MM=1,NOH
       IF(SOG(MM)+1.)  4001,4002,4001
 4001  CONTINUE
       HDIG=ACOS(COG(MM))*FACT
       GO TO 4003
 4002  CONTINUE
       HDIG=180.
 4003  CONTINUE
       DO 999 JJ=1,NOB
```

```
      VKNOTS = SQRT(ELL*GRAV)*FN(JJ)/1.689
      DO 599 INSTP=1,NWSTP
      IF (INWSTP(IWSTP) .LE. 0) INWSTP(IWSTP) = 90
      WSTP = 1./FLOAT(INWSTP(IWSTP))
      ASLOPE = 180.*WSTP
      KTH=KTH+1
      ITERAT = 0
      IF (THMO(KTH) .GT. 0.) GO TO 1500
      IF (HDG1(MM) .EQ. 180. .OR. HDG1(MM) .EQ. 0.) THMO(KTH) = .00175
      IF (HDG1(MM) .EQ. 90. .OR. HDG1(MM) .EQ. 270.) THMO(KTH) = .2
      IF (THMO(KTH) .LE. 0.) THMO(KTH) = .2
 1500 ITERAT = ITERAT + 1
      THM=THMO(KTH)
C
C   BY CALLING TANAKA THE EDDYMAKING COEFFICIENTS FOR THE STATIONS ARE
C       CALCULATED
C
      CALL TANAKA(THM,EDDY,RG8)
      DO 612 LL=1,NUK
      HDIG1 = 180.0 - HDIG
      TOP=6.283185
      GXI=ABS(SQRT(TOP/BAM(LL))+TOP*FN(JJ)*COG(MM)/BAM(LL))
C
C  GXI IS THE NON-DIMENSIONALIZED FREQUENCY OF ENCOUNTER.  IT IS
C      DIMENSIONALIZED BY MULTIPLICATION WITH SQRT(G/L).
C
      IF(GXI-0.05)  5002,5002,5003
C
C  THE ABOVE TEST IS MADE TO EXCLUDE THE CASE OF GXI=0.0.  THIS HAS
C  IMPORTANCE FOR THE FOLLOWING SEA CASE.
C
 5002 CONTINUE
      GXI=0.05
 5003 CONTINUE
      WE(LL) = GXI*SGL
      ZN(LL) = GXI
       WVLNTH = BAM(LL)*ELL
      WAVAMP(LL)=WSTP*WVLNTH/2.
       XLILMD(LL) = 1./BAM(LL)
      UN=0.5*GXI**2
      DO 200 L=1,6
      DO 200 M=1,6
      DA(L,M)=0.0
  200 DB(L,M)=0.0
      DO 1 N=2,NFR
       ITEMP = N
      DIFF=OMEN(N)-GXI*SQRT(0.5)
      IF(DIFF)    1,3,3
    1 CONTINUE
    3 CONTINUE
       N = ITEMP
      DELT1=OMEN(N)-OMEN(N-1)
      NON=NOT-1
      NUMB=6*NON
       K1 = NUMB
       K2 = 2*NUMB
       K3 = 3*NUMB
```

```
      NSKIP = 2*(N-2)*NUMB
      NELEM = 2*NFR*NUMB
      DELT0 = GXI*SQRT(0.5) - OMEN(N-1)
      TERM = DELT0/DELT1
C
C     THE FOLLOWING PROCEDURE READS IN FROM DRUM STORAGE THE PRESSURES,
C     CALCULATED IN SPRG2, NECESSARY TO CALCULATE THE PRESSURE AT THE GXI
C     FREQUENCY.  PRESSURE MEANS PRESSURE PER UNIT MOTION.  PAA AND PAV A
C     PRESSURES
C
      DO 350  K=1,NOSHAL
      READ (20) (A(I),I=1,NELEM)
      DO 350  J=1,NCN
      KM = (J-1)*6 + NSKIP
      DO 350  M=1,6
      KM = KM + 1
      AR1 = A(KM)
      AR2 = A(KM+K1)
      AT1 = A(KM+K2)
      AT2 = A(KM+K3)
      DELT4 = AT1 - AR1
      DELT5 = AT2 - AR2
      PAA(K,J,M) = AR1 + DELT4*TERM
      PAV(K,J,M) = AR2 + DELT5*TERM
  350 CONTINUE
      REWIND 20
      DO 202 L=1,10
      DELT2=(ALFA(N,L)-ALFA(N-1,L))/DELT1
      DELT3=(BETA(N,L)-BETA(N-1,L))/DELT1
      DA1(L)=ALFA(N-1,L)+DELT2*(GXI*SQRT(0.5)-OMEN(N-1))
      DB1(L)=BETA(N-1,L)+DELT3*(GXI*SQRT(0.5)-OMEN(N-1))
  202 CONTINUE
C
C     VISC IS CALLED TO CALCULATE SKIN FRICTION AND EDDYMAKING DAMPING.
C
      CALL VISC(GXI,VD,TVD,THM,EDDY,RGB)
      TBKD=0.0
      DO 4  K=1,NOS
      SBKD(K)=0.0
    4 CONTINUE
      IF(IBILG_-1) 3003,3003,3004
 3003 CONTINUE
C
C     BILGEK IS CALLED TO CALCULATE ROLL DAMPING DUE TO BILGEKEELS.
C
      CALL BILGEK(GXI,THM,SBKD,TBKD)
 3004 CONTINUE
C
C     DA ARE ADDED MASS COEFFICIENTS. DB ARE DAMPING COEFFICIENTS.  BOTH
C     ARE FOR THE WHOLE SHIP.
C
C
      DA(1,1)=DA1(1)
      DB(1,1)=DB1(1)
      DA(2,2)=DA1(2)
      DB(2,2)=DB1(2)
      DA(3,3)=DA1(3)
```

```
      DB(3,3)=DB1(3)
      DA(2,4)=DA1(9)
      DB(2,4)=DB1(9)
      DA(2,6)=DA1(8)-FN(JJ)/GXI**2*DB1(2)
      DB(2,6)=DB1(8)+FN(JJ)*DA1(2)
      DA(3,5)=DA1(7)+FN(JJ)/GXI**2*DB1(3)
      DB(3,5)=DB1(7)-FN(JJ)*DA1(3)
      DA(4,4)=DA1(4)
      DB(4,4)=DB1(4)
      DB(4,4)=DB(4,4)+TVD+TBKD
      DA(4,2)=DA(2,4)
      DB(4,2)=DB(2,4)
      DA(4,6)=DA1(10)-FN(JJ)/GXI**2*DB1(9)
      DB(4,6)=DB1(10)+FN(JJ)*DA1(9)
      DA(5,3)=DA1(7)-FN(JJ)/GXI**2*DB1(3)
      DB(5,3)=DB1(7)+FN(JJ)*DA1(3)
      DA(5,5)=DA1(5)+(FN(JJ)/GXI)**2*DA1(3)
      DB(5,5)=DB1(5)+(FN(JJ)/GXI)**2*DB1(3)
      DA(6,2)=DA1(8)+FN(JJ)/GXI**2*DB1(2)
      DB(6,2)=DB1(8)-FN(JJ)*DA1(2)
      DA(6,4)=DA1(10)+FN(JJ)/GXI**2*DB1(9)
      DB(6,4)=DB1(10)-FN(JJ)*DA1(9)
      DA(6,6)=DA1(6)+(FN(JJ)/GXI)**2*DA1(2)
      DB(6,6)=DB1(6)+(FN(JJ)/GXI)**2*DB1(2)
      IF(IEND-1) 3001,3001,3002
 3001 CONTINUE
C
C     ENDSEP CALCULATES THE ADDED-MASS AND DAMPING TERMS THAT ARISE FROM
C     SEPARATION OF THE FLOW ABOUT THE HULL.
C
      CALL ENDSEP(DA,DB,GXI,PAA,PAV,JJ)
 3002 CONTINUE
C
C     THE FOLLOWING PROCEDURE CREATES THE COEFFICIENT MATRICIES TOD AND T
C     THESE MATRICIES ARE USED TO SOLVE THE TWO SETS OF COUPLED DIFFERENT
C     EQUATIONS FOR THE MOTIONS.  IN MATRIX FORM THEY ARE-   TOD*X=BOD  A
C     TEV*X=BEV.  THE FIRST EQUATION IS FOR THE SURGE, HEAVE, AND PITCH.
C     THE SECOND EQUATION IS FOR THE SWAY, ROLL AND YAW.
C
      DO 109 I=1,3
      DO 110 J=1,3
      IEV=I+I
      JEV=J+J
      IOD=IEV-1
      JOD=JEV-1
      TOD(I,J)=-GXI**2*(GMU(IOD,JOD)+DA(IOD,JOD))
      TOD(I,J+3)=GXI*DB(IOD,JOD)
      TOD(I+3,J+3)=TOD(I,J)
      TOD(I+3,J)=-TOD(I,J+3)
      TEV(I,J)=-GXI**2*(GMU(IEV,JEV)+DA(IEV,JEV))
      TEV(I,J+3)=GXI*DB(IEV,JEV)
      TEV(I+3,J+3)=TEV(I,J)
      TEV(I+3,J)=-TEV(I,J+3)
  110 CONTINUE
  109 CONTINUE
      TOD(2,2)=TOD(2,2)+C33
      TOD(2,3)=TOD(2,3)+C35
```

```
      TOD(3,2)=TOD(3,2)+C35                                             SP5     299
      TOD(3,3)=TOD(3,3)+C55                                             SP5     300
      TOD(5,5)=TOD(2,2)                                                 SP5     301
      TOD(5,6)=TOD(2,3)                                                 SP5     302
      TOD(6,5)=TOD(3,2)                                                 SP5     303
      TOD(6,6)=TOD(3,3)                                                 SP5     304
      TEV(2,2)=TEV(2,2)+C44                                             SP5     305
      TEV(5,5)=TEV(2,2)                                                 SP5     306
C     *     *     *     *     *     *     *     *     *     *     *     * FMOD    129
C    FOR A HULLBORNE HYDROFOIL (IFOIL=2), SUBROUTINE -FOIL- CALCULATES  FMOD    130
C    THE MOTION COEFFICIENTS AND THE EXCITATION FORCES AND MOMENTS DUE  FMOD    131
C    TO THE FOILS. RETURNED ARE THE TERMS FOR THE TOD, BOD, TEV, AND    FMOD    132
C    BEV MATRICIES                                                      FMOD    133
C                                                                       FMOD    134
      IF(IFOIL-1) 7200,7200,7100                                        FMOD    135
 7100 CALL FOIL(TODF,TEVF,BODF,BEVF,VKNOTS,WAVAMP,HDG1,GXI,ELL,RHO,NF,CP FMOD    136
     2L,SPAN,CHORD,S,YF,ZF,DGAMMA,CLZ,ASP,THAS,T,LL)                    FMOD    137
      DO 7110 JA=1,6                                                    FMOD    138
      DO 7112 JB=1,6                                                    FMOD    139
      TODA(JA,JB)=TOD(JA,JB)                                            FMOD    140
      TEVA(JA,JB)=TEV(JA,JB)                                            FMOD    141
      TOD(JA,JB)=TOD(JA,JB)+TODF(JA,JB)                                 FMOD    142
      TEV(JA,JB)=TEV(JA,JB)+TEVF(JA,JB)                                 FMOD    143
      TODB(JA,JB)=TOD(JA,JB)                                            FMOD    144
      TEVB(JA,JB)=TEV(JA,JB)                                            FMOD    145
 7112 CONTINUE                                                          FMOD    146
 7110 CONTINUE                                                          FMOD    147
 7200 CONTINUE                                                          FMOD    148
C     *     *     *     *     *     *     *     *     *     *     *     * FMOD    149
      DO 1010  L=1,6                                                    SP5     307
      CFX(L)=(0.0,0.0)                                                  SP5     308
 1010 CONTINUE                                                          SP5     309
      INOS=0                                                            SP5     310
C                                                                       SP5     311
C    THE EXCITING FORCES AND MOMENTS  FOR THE WHOLE SHIP (BOD AND BEV) A SP5     312
C    NOW CALCULATED.  PEXR AND PEXI ARE THE FORCES AND MOMENTS FOR SECTI SP5     313
C                                                                       SP5     314
      DO 32 K=1,NOS                                                     SP5     315
      KO=K                                                              SP5     316
      HN=TOP/BAM(LL)/2.                                                 SP5     317
      CP=HN*(ST(K)-TPST)*COG(MM)                                        SP5     318
      CP1=COS(CP)                                                       SP5     319
      CP2=SIN(CP)                                                       SP5     320
      CPET=(CP1+II*CP2)*DS(K)                                           SP5     321
      DIP=ST(K)-TPST                                                    SP5     322
      DO 1643 I=1,NON                                                   SP5     323
      FR(I,1)=EN1(K,I)                                                  SP5     324
      FR(I,2)=-SNE(K,I)                                                 SP5     325
      FR(I,3)=CSE(K,I)                                                  SP5     326
      FR(I,4)=XX(K,I)*CSE(K,I)-YY(K,I)*FR(I,2)                          SP5     327
      FR(I,5)=-DIP*FR(I,3)                                              SP5     328
      FR(I,6)=DIP*FR(I,2)                                               SP5     329
 1643 CONTINUE                                                          SP5     330
      DO 1001 L=1,6                                                     SP5     331
 1001 CSUM(L)=(0.0,0.0)                                                 SP5     332
      DO 610 L=1,6                                                      SP5     333
      DEF(L)=0.0                                                        SP5     334
```

```
  610 CONTINUE
      DO 71 J=1,NON
      PET=EXP(HN*YY(K,J))
      ARG=HN*AX(K,J)*SOG(MM)
      FC=COS(ARG)
      FS=SIN(ARG)
      CFAC(1)=FC*FR(J,1)
      CFAC(3)=FC*FR(J,3)
      CFAC(5)=FC*FR(J,5)
      CFAC(2)=II*FS*FR(J,2)
      CFAC(4)=II*FS*FR(J,4)
      CFAC(6)=II*FS*FR(J,6)
      PP=FR(J,3)
      QQ=II*FR(J,2)*SOG(MM)
      DODD=(PP*FC+II*QQ*FS)*(GXI    *SQRT(0.5*WN)/UN)
      DEVEN=(QQ*FC+II*PP*FS)*(GXI    *SQRT(0.5*WN)/UN)
      DUM3=CFAC(3)
      DUM2=CFAC(2)
      CFAC(1)=CFAC(1)-DODD*CMPLX(PAA(K,J,1),PAV(K,J,1))
      CFAC(3)=CFAC(3)-DODD*CMPLX(PAA(K,J,3),PAV(K,J,3))
      CFAC(5)=CFAC(5)-DODD*CMPLX(PAA(K,J,5),PAV(K,J,5))
      CFAC(2)=CFAC(2)-DEVEN*CMPLX(PAA(K,J,2),PAV(K,J,2))
      CFAC(4)=CFAC(4)-DEVEN*CMPLX(PAA(K,J,4),PAV(K,J,4))
      CFAC(6)=CFAC(6)-DEVEN*CMPLX(PAA(K,J,6),PAV(K,J,6))
      CFAC(5)=CFAC(5)+(2.*II*FN(JJ)/GXI)*(CFAC(3)-DUM3)
      CFAC(6)=CFAC(6)-(2.*II*FN(JJ)/GXI)*(CFAC(2)-DUM2)
      DO 1002 L=1,6
 1002 CSUM(L)=CSUM(L)+PET*DEL(K,J)*CFAC(L)
      DEF(3)=DEF(3)-DODD*CMPLX(PAA(K,J,3),PAV(K,J,3))*PET*DEL(K,J)*4.
      DEF(5)=DEF(5)-DODD*CMPLX(PAA(K,J,5),PAV(K,J,5))*PET*DEL(K,J)*2.
      DEF(2)=DEF(2)-DEVEN*CMPLX(PAA(K,J,2),PAV(K,J,2))*PET*DEL(K,J)*4.
      DEF(4)=DEF(4)-DEVEN*CMPLX(PAA(K,J,4),PAV(K,J,4))*PET*DEL(K,J)*2.
      DEF(6)=DEF(6)-DEVEN*CMPLX(PAA(K,J,6),PAV(K,J,6))*PET*DEL(K,J)*2.
   71 CONTINUE
      DO  10 L=1,6
      PEXR(L,KO)=REAL(CSUM(L)*CPET)/TVOL
      PEXI(L,KO)=AIMAG(CSUM(L)*CPET)/TVOL
   10 CONTINUE
      PEXR(1,KO)=4.0*PEXR(1,KO)
      PEXR(2,KO)=4.0*PEXR(2,KO)
      PEXR(3,KO)=4.0*PEXR(3,KO)
      PEXR(4,KO)=2.0*PEXR(4,KO)
      PEXR(5,KO)=2.0*PEXR(5,KO)
      PEXR(6,KO)=2.0*PEXR(6,KO)
      PEXI(6,KO)=2.0*PEXI(6,KO)
      PEXI(5,KO)=2.0*PEXI(5,KO)
      PEXI(4,KO)=2.0*PEXI(4,KO)
      PEXI(3,KO)=4.0*PEXI(3,KO)
      PEXI(2,KO)=4.0*PEXI(2,KO)
      DO 611 L=1,6
      POFR(L,K)=REAL(DEF(L)*CPET*II)/TVOL/GXI/DS(K)*2.*FN(JJ)
      POFI(L,K)=AIMAG(DEF(L)*CPET*II)/TVOL/GXI/DS(K)*2.*FN(JJ)
  611 CONTINUE
      DO 1003 L=1,6
 1003 CFX(L)      =CFX(L)      +CPET*CSUM(L)
   32 CONTINUE
      DO 103 L=1,3
```

```
      LEV=L+L
      LOD=LEV-1
      BOD(L,1)=REAL(CFX(LOD))/TVOL
      BOD(L+3,1)=AIMAG(CFX(LOD))/TVOL
      BEV(L,1)=REAL(CFX(LEV))/TVOL
      BEV(L+3,1)=AIMAG(CFX(LEV))/TVOL
  103 CONTINUE
      BOD(1,1)=4.0*BOD(1,1)
      BOD(2,1)=4.0*BOD(2,1)
      BOD(3,1)=2.0*BOD(3,1)
      BOD(4,1)=4.0*BOD(4,1)
      BOD(5,1)=4.0*BOD(5,1)
      BOD(6,1)=2.0*BOD(6,1)
      BEV(1,1)=4.0*BEV(1,1)
      BEV(2,1)=2.0*BEV(2,1)
      BEV(3,1)=2.0*BEV(3,1)
      BEV(4,1)=4.0*BEV(4,1)
      BEV(5,1)=2.0*BEV(5,1)
      BEV(6,1)=2.0*BEV(6,1)
C
C     BOD(1,1)= REAL PART(SURGE/H)          BOD(4,1)=IMAGINARY PART(SURG
C     BEV(1,1)=REAL PART(SWAY/H)            BEV(4,1)=IMAGINARY PART(SWAY
C     BOD(2,1)=REAL PART(HEAVE/H)           BOD(5,1)=IMAGINARY PART(HEAV
C     BEV(2,1)=REAL PART(ROLL*L/H)          BEV(5,1)=IMAGINARY PART(ROLL
C     BOD(3,1)=REAL PART(PITCH*L/H)         BOD(6,1)=IMAGINARY PART(PITC
C     BEV(3,1)=REAL PART(YAW*L/H)           BEV(6,1)=IMAGINARY PART(YAW*
C
C   *    *    *    *    *    *    *    *    *    *    *    *
      IF(IFOIL-1) 7600,7600,7500
 7500 DO 7510 JA=1,6
      BODA(JA)=BOD(JA,1)
      BEVA(JA)=BEV(JA,1)
      BOD(JA,1)=BOD(JA,1)+BODF(JA)
      BEV(JA,1)=BEV(JA,1)+BEVF(JA)
      BODB(JA)=BOD(JA,1)
      BEVB(JA)=BEV(JA,1)
 7510 CONTINUE
 7600 CONTINUE
C   *    *    *    *    *    *    *    *    *    *    *    *
        BOV(LL,1,1) = BOD(1,1)
        BOV(LL,1,2) = BOD(4,1)
        BOV(LL,2,1) = BEV(1,1)
        BOV(LL,2,2) = BEV(4,1)
        BOV(LL,3,1) = BOD(2,1)
        BOV(LL,3,2) = BOD(5,1)
        BOV(LL,4,1) = BEV(2,1)
        BOV(LL,4,2) = BEV(5,1)
        BOV(LL,5,1) = BOD(3,1)
        BOV(LL,5,2) = BOD(6,1)
        BOV(LL,6,1) = BEV(3,1)
        BOV(LL,6,2) = BEV(6,1)
C
C     MATINS IS USED TO SOLVE THE EQUATIONS OF MOTION.
C
      CALL MATINS(TOD,6,6,BOC,1,1,DTRM,IO,INDEX)
      DO 8201 IQ=1,6
      BODC(IQ)=BOD(IQ,1)
```

```
      DO 8202 JQ=1,6                                                   FMOD      164
 8202 TODC(IQ,JQ)=TOD(IQ,JQ)                                           FMOD      165
 8201 CONTINUE                                                         FMCD      166
      IF(ID-1) 501,501,502                                             FMOD      167
  501 CALL MATINS(TEV,6,6,BEV,1,1,DTRM,ID,INDEX)                       SP5       436
      DO 8203 IQ=1,6                                                   FMOC      168
      BEVC(IQ)=BEV(IQ,1)                                               FMOD      169
      DO 8204 JQ=1,6                                                   FMCD      170
 8204 TEVC(IQ,JQ)=TEV(IQ,JQ)                                           FMOD      171
 8203 CONTINUE                                                         FMCD      172
      IF(ID-1) 503,503,502                                             FMOD      173
  502 DO 105 L=1,6                                                     SP5       438
  105 CFX(L)      =(0.0,0.0)                                           SP5       439
      GO TO 999                                                        SP5       440
  503 CONTINUE                                                         SP5       441
      RMO(1,LL)=BOD(1,1)                                               SP5       442
      RMO(2,LL)=BEV(1,1)                                               SP5       443
      RMO(3,LL)=BOD(2,1)                                               SP5       444
      RMO(4,LL)=BEV(2,1)                                               SP5       445
      RMO(5,LL)=BOD(3,1)                                               SP5       446
      RMO(6,LL)=BEV(3,1)                                               SP5       447
      AIMO(1,LL)=BOD(4,1)                                              SP5       448
      AIMO(2,LL)=BEV(4,1)                                              SP5       449
      AIMO(3,LL)=BOD(5,1)                                              SP5       450
      AIMO(4,LL)=BEV(5,1)                                              SP5       451
      AIMO(5,LL)=BOD(6,1)                                              SP5       452
      AIMO(6,LL)=BEV(6,1)                                              SP5       453
      RMO(4,LL)=RMO(4,LL)*BAM(LL)                                      SP5       454
      RMO(5,LL)=RMO(5,LL)*BAM(LL)                                      SP5       455
      RMO(6,LL)=RMO(6,LL)*BAM(LL)                                      SP5       456
      AIMO(4,LL)=AIMO(4,LL)*BAM(LL)                                    SP5       457
      AIMO(5,LL)=AIMO(5,LL)*BAM(LL)                                    SP5       458
      AIMO(6,LL)=AIMO(6,LL)*BAM(LL)                                    SP5       459
      THUAL(LL)=SQRT(RMO(4,LL)**2+AIMO(4,LL)**2)*WAVAMP(LL)/WVLNTH     SP5       460
      IF(IPRES-1) 5202,5202,5203                                       FMOD      174
 5202 CONTINUE                                                         SP5       462
C                                                                      SP5       463
C     HYDPRE CALCULATES THE TOTAL HYDRODYNAMIC PRESSURE.               SP5       464
C                                                                      SP5       465
      CALL HYDPRE(WN,BOD,BEV,PAA,PAV,GXI,PRERE,PREIM,JJ,MM)            SP5       466
       IRMO = LL - (LL/2)*2                                            SP5       467
       IF (IRMO .EQ. 1) WRITE (6,700)                                  SP5       468
  700  FORMAT (*1PRESSURE DISTRIBUTION ON THE HULL FOR THE SPECIFIED * SP5       469
     2 *CONDITIONS*)                                                   SP5       470
       WRITE (6,698) HDIG1,FN(JJ),BAM(LL)                              SP5       471
  698  FORMAT (///12H CONDITIONS-/9H0HEADING=F10.4,5X,                 SP5       472
     2 15H FROUDE-NUMBER=F10.4,5X,14H WAVELENGTH/L=F10.4)              SP5       473
      WRITE(6,697)                                                     SP5       474
  697 FORMAT(//)                                                       SP5       475
      WRITE(6,550)                                                     SP5       476
  550 FORMAT(40X,22H PRESSURE DISTRIBUTION)                            SP5       477
      KPA=0                                                            SP5       478
      DO 5204 K=1,NOS                                                  SP5       479
      IF (STFR(K)) 5205,5204,5205                                      SP5       480
 5205 CONTINUE                                                         SP5       481
      KPA=KPA+1                                                        SP5       482
      WRITE (6,5206)K                                                  SP5       483
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5206 FORMAT(73H0AMPLITUDE AND PHASE OF THE PRESSURE FOR THE SPECIFIED P SP5       484
    1OINTS ON SECTION I2)                                               SP5       485
     WRITE(6,5207)                                                      SP5       486
5207 FORMAT(25X,13H Y-COORDINATE,5X,13H Z-COORDINATE,7X,10H AMPLITUDE,1 SP5       487
    12X,6H PHASE)                                                       SP5       488
     DO 5208 JS=1,2                                                     SP5       489
     IF(JS-1) 6222,6222,6223                                            FMOD      175
6222 CONTINUE                                                           SP5       491
     CSP=1.0                                                            SP5       492
     WRITE(6,6224)                                                      SP5       493
6224 FORMAT(16H STARBOARD SIDE )                                        SP5       494
     GO TO 6225                                                         SP5       495
6223 CONTINUE                                                           SP5       496
     CSP=-1.0                                                           SP5       497
     WRITE(6,6226)                                                      SP5       498
6226 FORMAT(11H PORT SIDE )                                             SP5       499
6225 CONTINUE                                                           SP5       500
     DO 5209 J=1,NON                                                    SP5       501
     JM=J+NON*(JS-1)                                                    SP5       502
     YPRES=XX(K,J)*EL*CSP                                               SP5       503
     ZPRES=YY(K,J)*EL                                                   SP5       504
     AV=SQRT(PRERE(KPA,JM)**2+PREIM(KPA,JM)**2)                         SP5       505
     IF(PREIM(KPA,JM)) 751,752,751                                      SP5       506
 752 IF(PRERE(KPA,JM)) 751,753,751                                      SP5       507
 753 PH=0.0                                                             SP5       508
     GO TO 754                                                          SP5       509
 751 PH=ATAN2(PREIM(KPA,JM),PRERE(KPA,JM))*FACT                         SP5       510
 754 CONTINUE                                                           SP5       511
     WRITE(6,5210) YPRES,ZPRES,AV,PH                                    SP5       512
5210 FORMAT(25X,F10.4,10X,F10.4,10X,F10.4,10X,F10.4)                    SP5       513
5209 CONTINUE                                                           SP5       514
5208 CONTINUE                                                           SP5       515
5204 CONTINUE                                                           SP5       516
5203 CONTINUE                                                           SP5       517
      IF (ML .EQ. 2) CALL LOADS                                         SP5       518
 612 CONTINUE                                                           SP5       519
C-----TEST FOR CONVERGENCE OF ROLL ANGLE-------------------------------- SP5       520
     RHMD(KTH)=AMAX(NOK,THCAL)                                          SP5       521
     THDIFF = THMD(KTH) - RHMD(KTH)                                     SP5       522
     THDRAD = ABS(THDIFF)                                               SP5       523
     IHMD(KTH) = ITERAT                                                 SP5       524
     HMD(ITERAT,KTH,1) = THMD(KTH)                                      SP5       525
     HMD(ITERAT,KTH,2) = PHMD(KTH)                                      SP5       526
     IF (THDRAD .LE. EPS) GO TO 1505                                    SP5       527
     IF (ITERAT .EQ. 5) GO TO 1505                                      SP5       528
     THMD(KTH) = THMD(KTH) - SIGN(1.,THDIFF)*FCT*THDRAD                 SP5       529
     GO TO 1500                                                         SP5       530
1505 IF(IFOIL-1) 2401,2401,2402                                         FMOD      176
2402 WRITE(6,2198)                                                      FMOD      177
     DO 5614 JH=1,2                                                     FMOD      178
     IF(JH .EQ. 1) H=1                                                  FMOD      179
     IF(JH .EQ. 2) H=6                                                  FMOD      180
     IF(H .EQ. 6 .AND. FRNTOP .EQ. MIN) GO TO 5614                      FMOD      181
     WRITE(H,2199) TITO,HDIG1,VKNOTS,FN(JJ)                             FMOD      182
5614 CONTINUE                                                           FMOD      183
     WRITE(6,2200)                                                      FMOD      184
     WRITE(6,2201)                                                      FMOD      185
```

```
      DO 2300 LX=1,NOK                                                  FMOD
      LWEINC=NOK-LX+1                                                   FMOD
 2300 WRITE(6,2202)     ZN(LWEINC),(T(LWEINC,KX),KX=1,10)               FMOD
      WRITE(6,2204)                                                     FMOD
      WRITE(6,2205)                                                     FMOD
      DO 2301 LX=1,NOK                                                  FMOD
      LWEINC=NOK-LX+1                                                   FMOD
      WRITE(6,2202)     ZN(LWEINC),(T(LWEINC,KX),KX=11,20)              FMOD
 2301 WRITE(6,2203) (T(LWEINC,KX),KX=21,30)                             FMOD
      WRITE(6,2206)                                                     FMOD
      WRITE(6,2207)                                                     FMOD
      DO 2302 LX=1,NOK                                                  FMOD
      LWEINC=NOK-LX+1                                                   FMOD
      WRITE(6,2202)     ZN(LWEINC),(T(LWEINC,KX),KX=31,40)              FMOD
 2302 WRITE(6,2203) (T(LWEINC,KX),KX=41,50)                             FMOD
      WRITE(6,2208)                                                     FMOD
      WRITE(6,2209)                                                     FMOD
      DO 2303 LX=1,NOK                                                  FMOD
      LWEINC=NOK-LX+1                                                   FMOD
      WRITE(6,2210)     ZN(LWEINC),(T(LWEINC,KX),KX=51,56)              FMOD
 2303 WRITE(6,2211) (T(LWEINC,KX),KX=57,62)                             FMOD
      IF(IPRINT) 2401,2401,8000                                         FMOD
 8000 WRITE(6,8001)                                                     FMOD
      DO 8101 IQ=1,3                                                    FMOD
      JQ=IQ+IQ-1                                                        FMOD
 8101 WRITE(6,8021) (TODA(IQ,KQ),KQ=1,6),JQ,BODA(IQ)                    FMOD
      DO 8102 IQ=4,6                                                    FMOD
      JQ=IQ+IQ-7                                                        FMOD
 8102 WRITE(6,8022) (TODA(IQ,KQ),KQ=1,6),JQ,BODA(IQ)                    FMOD
      WRITE(6,8002)                                                     FMOD
      DO 8103 IQ=1,3                                                    FMOD
      JQ=IQ+IQ-1                                                        FMOD
 8103 WRITE(6,8021) (TODF(IQ,KQ),KQ=1,6),JQ,BODF(IQ)                    FMOD
      DO 8104 IQ=4,6                                                    FMOD
      JQ=IQ+IQ-7                                                        FMOD
 8104 WRITE(6,8022) (TODF(IQ,KQ),KQ=1,6),JQ,BODF(IQ)                    FMOD
      WRITE(6,8003)                                                     FMOD
      DO 8105 IQ=1,3                                                    FMOD
      JQ=IQ+IQ-1                                                        FMOD
 8105 WRITE(6,8021) (TODB(IQ,KQ),KQ=1,6),JQ,BODB(IQ)                    FMOD
      DO 8106 IQ=4,6                                                    FMOD
      JQ=IQ+IQ-7                                                        FMOD
 8106 WRITE(6,8022) (TODB(IQ,KQ),KQ=1,6),JQ,BODB(IQ)                    FMOD
      WRITE(6,8004)                                                     FMOD
      DO 8107 IQ=1,6                                                    FMOD
 8107 WRITE(6,8023) BODC(IQ),(TODC(IQ,KQ),KQ=1,6),BODB(IQ)              FMOD
      WRITE(6,8011)                                                     FMOD
      DO 8108 IQ=1,3                                                    FMOD
      JQ=IQ+IQ                                                          FMOD
 8108 WRITE(6,8021) (TEVA(IQ,KQ),KQ=1,6),JQ,BEVA(IQ)                    FMOD
      DO 8109 IQ=4,6                                                    FMOD
      JQ=IQ+IQ-6                                                        FMOD
 8109 WRITE(6,8022) (TEVA(IQ,KQ),KQ=1,6),JQ,BEVA(IQ)                    FMOD
      WRITE(6,8012)                                                     FMOD
      DO 8110 IQ=1,3                                                    FMOD
      JQ=IQ+IQ                                                          FMOD
 8110 WRITE(6,8021) (TEVF(IQ,KQ),KQ=1,6),JQ,BEVF(IQ)                    FMOD
```

```
      DO 8111 IQ=4,6                                                    FMOD    243
      JQ=IQ+IQ-6                                                        FMOD    244
 8111 WRITE(6,8022) (TEVF(IQ,KQ),KQ=1,6),JQ,BEVF(IQ)                    FMOD    245
      WRITE(6,8013)                                                     FMOD    246
      DO 8112 IQ=1,3                                                    FMOD    247
      JQ=IQ+IQ                                                          FMOD    248
 8112 WRITE(6,8021) (TEVB(IQ,KQ),KQ=1,6),JQ,BEVB(IQ)                    FMOD    249
      DO 8113 IQ=4,6                                                    FMOD    250
      JQ=IQ+IQ-6                                                        FMOD    251
 8113 WRITE(6,8022) (TEVB(IQ,KQ),KQ=1,6),JQ,BEVB(IQ)                    FMOD    252
      WRITE(6,8014)                                                     FMOD    253
      DO 8114 IQ=1,6                                                    FMOD    254
 8114 WRITE(6,8023) BEVC(IQ),(TEVC(IQ,KQ),KQ=1,6),BEVG(IQ)              FMOD    255
 2401  IF (INSTP .EQ. 1) CALL EXCFM                                     FMOD    256
      CALL MOTOUT                                                       SP5     532
       IF (ML .EQ. 1) GO TO 781                                         SP5     533
       ITEMP = PRNTOP                                                   SP5     534
       NOSM1 = NOS - 1                                                  SP5     535
      DO 780 ISTAT=1,NOSM1                                              SP5     536
       PRNTOP = MIN                                                     SP5     537
       IF (STLD(ISTAT) .GT. 0.) PRNTOP = ITEMP                          SP5     538
      CALL LODOUT(ISTAT)                                                SP5     539
  780  CONTINUE                                                         SP5     540
       PRNTOP = ITEMP                                                   SP5     541
  781  CONTINUE                                                         SP5     542
  998  CONTINUE                                                         SP5     543
  999 CONTINUE                                                          SP5     544
       CALL MOTABL                                                      SP5     545
      RETURN                                                            SP5     546
      END                                                               SP5     547
```

```
      SUBROUTINE FOIL(TODF,TEVF,BODF,BEVF,VKNOTS,WAMPL,HDG1,GXI,ELL,RHO,
     2NF,Q1,Q2,Q3,Q4,Q5,Q6,Q7,Q8,Q9,TMAS,T,NFREQ)
      COMMON /OFOIL/ GA(6,6)
      DIMENSION TODF(6,6),TEVF(6,6),BODF(6),BEVF(6)
      DIMENSION Q1(10),Q2(10),Q3(10),Q4(10),Q5(10),Q6(10),Q7(10),Q8(10),
     2Q9(10)
      DIMENSION GB(6,6),GC(6,6),GF(6),T(32,62),GAA(6,6)
      COMPLEX CK,B2,C2,P1B33,P1C33,P2B35,P1C35,P2C35,P1B22,P1B24,P1C24,P
     12B26,P1C26,P1B44,P2B44,P1C44,P2B46,P1C46,P1B53,P1C53,P3B55,P1C55,P
     22C55,P1B62,P1B64,P1C64,P2B66,P1C66
      COMPLEX C,EXL,EXM,AA,APG,HSIN,HCOS,V1,V2,W1,W2,PL1,PF2,PF3,PL2,PF4
     2,PM1,PF5,PF6,BB,W3
      COMPLEX GB,GC,GF
      P1A33=P1A35=P1B35=P1A22=P1A24=P1A26=P1B26=P1A44=P2A44=P1A46=P1B46=
     1P1A55=P1B55=P2B55=P1A66=P1B66=P3B66=0.
      P1B33=P1C33=P2B35=P1C35=P2C35=P1B22=P1B24=P1C24=P2B26=P1C26=P1B44=
     2P2B44=P1C44=P2B46=P1C46=P1B53=P3B55=P1C55=P2C55=P1B62=P1B64=P1C64=
     3P2B66=P1C66=(0.,0.)
      PF2=PF3=PF4=PF5=PF6=(0.,0.)
      DO 200 I=1,6
      GF(I)=(0.,0.)
      DO 201 J=1,6
      IF(NFREQ .EQ. 1) GA(I,J)=0.
      GB(I,J)=(0.,0.)
  201 GC(I,J)=(0.,0.)
  200 CONTINUE
C
C     MULTIPLICATION FACTORS FOR NON-DIM. ARE
C         ACCEL FORCES                (1./MASS)
C         VEL. FORCES                 (1./MASS)*SQRT(LPP/GRAV)
C         DISPL. FORCES               (1./MASS)*(LPP/GRAV)
C       SUBSCRIPTS  11,13,31,33,22
C
C         INERTIA MOMENTS             (1./MASS)/LPP**2
C         ANGULAR VEL. MOMENTS        (1./MASS)*SQRT(LPP/GRAV)/LPP**2
C         ANGULAR DISPL. MOMENTS      (1./MASS)*(LPP/GRAV)/LPP**2
C       SUBSCRIPTS  55,44,46,64,66
C
C         CROSS INERTIA               (1./MASS)/LPP
C         CROSS VEL.                  (1./MASS)*SQRT(LPP/GRAV)/LPP
C         CROSS DISPL.                (1./MASS)*(LPP/GRAV)/LPP
C       SUBSCRIPTS  15,35,51,53,24,26,42,62
C
C         EXCIT. FORCES/WAVE AMPL. LPP/(MASS*GRAV*WAMPL)
C       SUBSCRIPTS  1,2,3
C
C         EXCIT.MOM./WAVE AMPL.     1./(MASS*GRAV*WAMPL)
C       SUBSCRIPTS  4,5,6
C
      GRAV=32.2
      RMASS=1./TMAS
      ZLDIVG=ELL/GRAV
      ELLSQ=ELL*ELL
      FA1=RMASS
      FB1=RMASS*SQRT(ZLDIVG)
      FC1=RMASS*ZLDIVG
      FA2=FA1/ELLSQ
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```
      FB2=FB1/ELLSQ                                                     FOIL  59
      FC2=FC1/ELLSQ                                                     FOIL  60
      FA3=FA1/ELL                                                       FOIL  61
      FB3=FB1/ELL                                                       FOIL  62
      FC3=FC1/ELL                                                       FOIL  63
      FD1=ELL/(TMAS*GRAV*WAMPL)                                         FOIL  64
      FD2=FD1/ELL                                                       FOIL  65
C                                                                       FOIL  66
      PI=3.14159                                                        FOIL  67
      XMU=(180.0-HDG1)/57.2957795                                       FOIL  68
      U=VKNOTS*1.689                                                    FOIL  69
      SINMU=SIN(XMU)                                                    FOIL  70
      COSMU=COS(XMU)                                                    FOIL  71
      OMEGAE=GXI*SQRT(GRAV/ELL)                                         FOIL  72
      GDIVU=GRAV/(2.*U)                                                 FOIL  73
      OMEGA=-GDIVU+SQRT((GDIVU*GDIVU)+(2.*GDIVU*OMEGAE))                FOIL  74
      A1=PI*RHO                                                         FOIL  75
      A3=A1*U                                                           FOIL  76
      B1=0.5*RHO*U                                                      FOIL  77
      C1=B1*U                                                           FOIL  78
      BB=CMPLX(0.,1.)                                                   FOIL  79
C---------------------------------------------------------------------- FOIL  80
C     SUMMATIONS FOR FOIL COEFFICIENTS AND EXCITATION FORCES / MOMENTS  FOIL  81
C---------------------------------------------------------------------- FOIL  82
C                                                                       FOIL  83
      DO 100 I=1,NF                                                     FOIL  84
      CPL=Q1(I)                                                         FOIL  85
      SPAN=Q2(I)                                                        FOIL  86
      CHORD=Q3(I)                                                       FOIL  87
      S=Q4(I)                                                           FOIL  88
      Y=Q5(I)                                                           FOIL  89
      Z=Q6(I)                                                           FOIL  90
      DGAMMA=Q7(I)                                                      FOIL  91
      CLZ=Q8(I)                                                         FOIL  92
      ASP=Q9(I)                                                         FOIL  93
      NCPL=CPL                                                          FOIL  94
      AREA=SPAN*CHORD                                                   FOIL  95
      ASPRAT=SPAN/CHORD                                                 FOIL  96
      ASPCOR=ASPRAT/(ASPRAT+ASP)                                        FOIL  97
      CPL=CPL*ASPCOR                                                    FOIL  98
      GAMMA=DGAMMA/57.2957795                                           FOIL  99
      SING=SIN(GAMMA)                                                   FOIL 100
      SINGSQ=SING*SING                                                  FOIL 101
      COSG=COS(GAMMA)                                                   FOIL 102
      COSGSQ=COSG*COSG                                                  FOIL 103
      CLALPH=2.*PI                                                      FOIL 104
      XK1=0.5*OMEGAE*CHORD/U                                            FOIL 105
      XK2=(OMEGA*OMEGA)/GRAV                                            FOIL 106
      XK3=0.5*(OMEGAE*OMEGAE)*CHORD*COSMU/GRAV                          FOIL 107
      CALL THEO(XK1,CK)                                                 FOIL 108
      A2=0.25*AREA*CHORD*CPL                                            FOIL 109
      B2=AREA*CLALPH*CK*CPL                                             FOIL 110
      C2=CLZ*AREA*CK*CPL                                                FOIL 111
C  *    *    *    *    *    *    *    *    *    *    *    *    *    *   FOIL 112
      IF(NFREQ .GT. 1) GO TO 308                                        FOIL 113
      P1A33=P1A33+(A2*COSGSQ)                                           FOIL 114
      P1A35=P1A35+(A2*S*COSGSQ)                                         FOIL 115
```

```
      P1A55=P1A55+(A2*COSGSQ*(CHORD*CHORD/32.+S*S))                     FOIL
      P1A22=P1A22+(A2*SINGSQ)                                           FOIL
      P1A24=P1A24+((A2*Z*SINGSQ)+(A2*Y*SING*COSG))                      FOIL
      P1A26=P1A26+(A2*S*SINGSQ)                                         FOIL
      P1A44=P1A44+(AREA*AREA*SPAN/48.)*CPL                              FOIL
      P2A44=P2A44+(A2*((Z*SING+Y*COSG)**2))                             FOIL
      P1A46=P1A46+((A2*Z*S*SINGSQ)+(A2*Y*S*SING*COSG))                  FOIL
      P1A66=P1A66+(A2*SINGSQ*(CHORD*CHORD/32.+S*S))                     FOIL
  308 P1B33=P1B33+(B2*COSGSQ)                                           FOIL
      P1B35=P1B35+(A2*COSGSQ)                                           FOIL
      P2B35=P2B35+(B2*COSGSQ*(S+(CHORD/4.)))                            FOIL
      P1B53=P1B53+(B2*(S-(CHORD/4.))*COSGSQ)                            FOIL
      P1B55=P1B55+(A2*S*COSGSQ)                                         FOIL
      P2B55=P2B55+((CHORD**3)*SPAN*COSGSQ/16.)*CPL                      FOIL
      P3B55=P3B55+(B2*(S+(CHORD/4.))*(S-(CHORD/4.))*COSGSQ)             FOIL
      P1B22=P1B22+(B2*SINGSQ)                                           FOIL
      P1B24=P1B24+((B2*Z*SINGSQ)+(B2*Y*SING*COSG))                      FOIL
      P1B26=P1B26+(A2*SINGSQ)                                           FOIL
      P2B26=P2B26+(B2*(S+(CHORD/4.))*SINGSQ)                            FOIL
      P1B44=P1B44+(B2*SPAN*SPAN/12.)                                    FOIL
      P2B44=P2B44+(B2*((Z*SING+Y*COSG)**2))                             FOIL
      P1B46=P1B46+((A2*Z*SINGSQ)+(A2*Y*SING*COSG))                      FOIL
      P2B46=P2B46+(B2*(S+(CHORD/4.))*((Z*SINGSQ)+(Y*SING*COSG)))        FOIL
      P1B62=P1B62+(B2*(S-(CHORD/4.))*SINGSQ)                            FOIL
      P1B64=P1B64+(B2*(S-(CHORD/4.))*((Z*SINGSQ)+(Y*SING*COSG)))        FOIL
      P1B66=P1B66+(A2*S*SINGSQ)                                         FOIL
      P2B66=P2B66+(B2*(S+(CHORD/4.))*(S-(CHORD/4.))*SINGSQ)             FOIL
      P3B66=P3B66+((CHORD**3)*SPAN*SINGSQ/16.)*CPL                      FOIL
      P1C33=P1C33+(C2*COSG)                                             FOIL
      P1C35=P1C35+(B2*COSGSQ)                                           FOIL
      P2C35=P2C35+(C2*(S-(CHORD/4.))*COSG)                              FOIL
      P1C53=P2C35                                                       FOIL
      P1C55=P1C55+(B2*(S-(CHORD/4.))*COSGSQ)                            FOIL
      P2C55=P2C55+(C2*(S+(CHORD/4.))*(S-(CHORD/4.))*COSG)               FOIL
      P1C24=P1C24+(C2*Y*SING)                                           FOIL
      P1C26=P1C26+(B2*SINGSQ)                                           FOIL
      P1C64=P1C64+(C2*(S-(CHORD/4.))*Y*SING)                            FOIL
      P1C66=P1C66+(B2*(S-(CHORD/4.))*SINGSQ)                            FOIL
      P1C44=P1C44+(C2*Y*((Y*COSG)+(Z*SING)))                            FOIL
      P1C46=P1C46+((B2*Z*SINGSQ)+(B2*Y*SING*COSG))                      FOIL
C    *   *   *   *   *   *   *   *   *   *   *   *   *   *             FOIL
      CALL EXCIT(XK3,XK1,CK,EXL,EXM)                                    FOIL
   25 C=CMPLX(COSG,SINMUG)                                              FOIL
      XREAL=XK2*SING                                                    FOIL
      XIMAG=XK2*SINMU*COSG                                              FOIL
      AA=CMPLX(XREAL,-XIMAG)                                            FOIL
      ARG=0.5*AA*SPAN                                                   FOIL
      HSIN=0.5*(CEXP(ARG)-CEXP(-ARG))                                   FOIL
      HCOS=0.5*(CEXP(ARG)+CEXP(-ARG))                                   FOIL
      V1=(2./AA)*HSIN                                                   FOIL
      V2=(1./(AA*AA))*(AA*SPAN*HCOS-2.*HSIN)                            FOIL
      XREAL=XK2*Z                                                       FOIL
      XIMAG=-XK2*Y*SINMU                                                FOIL
      AA=CMPLX(XREAL,XIMAG)                                             FOIL
      AA=WAMPL*OMEGA*CEXP(AA)*C                                         FOIL
      W1=AA*V1*B8                                                       FOIL
      W2=AA*V2*B8                                                       FOIL
```

```
      W3=AA*BB
      IF(NCPL-1) 51,51,50
   50 W1=2.*W1
      W2=2.*W2
      W3=2.*W3
   51 XIMAG=-XK2*S*COSMU
      AA=CEXP(CMPLX(0.,XIMAG))
      C=CHORD*EXL*AA
      PL1=C*AIMAG(W1)*BB
      PF3=PF3+(PL1*COSG*ASPCOR)
      PL1=C*REAL(W1)
      PL2=CHORD*W2*EXL
      PM1=0.25*CHORD*CHORD*EXM*AA
      PF5=PF5-(((-S*PL1)-PM1*BB*AIMAG(W3))*COSG)*ASPCOR
      HD=HDG1
      IF(HD .GT. 180.) HD=HD-180.
      IF(HD .GT. 172.) GO TO 100
      IF(HD .LT. 8.) GO TO 100
      PF2=PF2-(PL1*SING*ASPCOR)
      PF4=PF4+(PL2+PL1*(Y*COSG+Z*SING))*ASPCOR
      PF6=PF6+(((S*PL1)+PM1*REAL(W3))*SING)*ASPCOR
  100 CONTINUE
C
C-----------------------------------------------------------------------
C     FOIL COEFFICIENTS  (NON-DIM.)
C---  ------------------------------------------------------------------
      IF(NFREQ .GT. 1) GO TO 310
      GA(3,3)=FA1*(+A1*P1A33)
      GA(3,5)=FA3*(-A1*P1A35)
      GA(5,3)=GA(3,5)
      GA(5,5)=FA2*(+A1*P1A55)
      GA(2,2)=FA1*(+A1*P1A22)
      GA(2,4)=FA3*(-A1*P1A24)
      GA(2,6)=FA3*(+A1*P1A26)
      GA(4,2)=GA(2,4)
      GA(4,4)=FA2*(+A1*(P1A44+P2A44))
      GA(4,6)=FA2*(-A1*P1A46)
      GA(6,2)=GA(2,6)
      GA(6,4)=GA(4,6)
      GA(6,6)=FA2*(+A1*P1A66)
  310 GB(3,3)=FB1*(+B1*P1B33)
      GB(3,5)=FB3*(-A3*P1B35-B1*P2B35)
      GB(5,3)=FB3*(-B1*P1B53)
      GB(5,5)=FB2*(+A3*P1B55+A3*P2B55+B1*P3B55)
      GB(2,2)=FB1*(+B1*P1B22)
      GB(2,4)=FB3*(-B1*P1B24)
      GB(2,6)=FB3*(+A3*P1B26+B1*P2B26)
      GB(4,2)=GB(2,4)
      GB(4,4)=FB2*(+B1*(P1B44+P2B44))
      GB(4,6)=FB2*(-A3*P1B46-B1*P2B46)
      GB(6,2)=FB3*(+B1*P1B62)
      GB(6,4)=FB2*(-B1*P1B64)
      GB(6,6)=FB2*(+A3*P1B66+B1*P2B66+A3*P3B66)
      GC(3,3)=FC1*(+C1*P1C33)
      GC(3,5)=FC3*(-C1*(P1C35+P2C35))
      GC(5,3)=FC3*(-C1*P1C53)
      GC(5,5)=FC2*(+C1*(P1C55+P2C55))
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      GC(2,4)=FC3*(-C1*P1C24)
      GC(2,6)=FC3*(+C1*P1C26)
      GC(4,4)=FC2*(+C1*P1C44)
      GC(4,6)=FC2*(-C1*P1C46)
      GC(6,4)=FC2*(-C1*P1C64)
      GC(6,6)=FC2*(+C1*P1C66)
      DO 400 K=1,6
      T(NFREQ,K)=GA(K,K)
      T(NFREQ,K+10)=REAL(GB(K,K))
      T(NFREQ,K+20)=AIMAG(GB(K,K))
      T(NFREQ,K+30)=REAL(GC(K,K)).
  400 T(NFREQ,K+40)=AIMAG(GC(K,K))
      T(NFREQ,7)=GA(3,5)
      T(NFREQ,8)=GA(2,6)
      T(NFREQ,9)=GA(2,4)
      T(NFREQ,10)=GA(4,6)
      T(NFREQ,17)= REAL(GB(3,5))
      T(NFREQ,27)=AIMAG(GB(3,5))
      T(NFREQ,18)= REAL(GB(2,6))
      T(NFREQ,28)=AIMAG(GB(2,6))
      T(NFREQ,19)= REAL(GB(2,4))
      T(NFREQ,29)=AIMAG(GB(2,4))
      T(NFREQ,20)= REAL(GB(4,6))
      T(NFREQ,30)=AIMAG(GB(4,6))
      T(NFREQ,37)= REAL(GC(3,5))
      T(NFREQ,47)=AIMAG(GC(3,5))
      T(NFREQ,38)= REAL(GC(2,6))
      T(NFREQ,48)=AIMAG(GC(2,6))
      T(NFREQ,39)= REAL(GC(2,4))
      T(NFREQ,49)=AIMAG(GC(2,4))
      T(NFREQ,40)= REAL(GC(4,6))
      T(NFREQ,50)=AIMAG(GC(4,6))
C
C     MULTIPLICATION OF ACCELERATION TERMS BY  -GXI*GXI
C     MULTIPLICATION OF VELOCITY TERMS BY  +GXI
C
      A=-GXI*GXI
      B=GXI
      DO 202 I=1,6
      DO 203 J=1,6
      GAA(I,J)=A*GA(I,J)
  203 GB(I,J)=B*GB(I,J)
  202 CONTINUE
C
C     FOIL COMPONENTS FOR MATRICIES  -TOD AND TEV-
C
      DO 205 I=1,3
      DO 206 J=1,3
      IEV=I+I
      JEV=J+J
      IOD=IEV-1
      JOD=JEV-1
      TODF(I,J)=GAA(IOD,JOD)-AIMAG(GB(IOD,JOD))+REAL(GC(IOD,JOD))
      TODF(I,J+3)=+REAL(GB(IOD,JOD))+AIMAG(GC(IOD,JOD))
      TODF(I+3,J+3)=TODF(I,J)
      TODF(I+3,J)=-TODF(I,J+3)
      TEVF(I,J)=GAA(IEV,JEV)-AIMAG(GB(IEV,JEV))+REAL(GC(IEV,JEV))
```

```
      TEVF(I,J+3)=+REAL(GB(IEV,JEV))+AIMAG(GC(IEV,JEV))
      TEVF(I+3,J+3)=TEVF(I,J)
      TEVF(I+3,J)=-TEVF(I,J+3)
  206 CONTINUE
  205 CONTINUE
C-----------------------------------------------------------------------
C     EXCITATION FORCES AND MOMENTS  (NON-DIM.)
C-----------------------------------------------------------------------
C
      GF(2)=FD1*(+A3*PF2)
      GF(3)=FD1*(+A3*PF3)
      GF(4)=FD2*(+A3*PF4)
      GF(5)=FD2*(+A3*PF5)
      GF(6)=FD2*(+A3*PF6)
      DO 402 K=1,6
      T(NFREQ,K+50)= REAL(GF(K))
  402 T(NFREQ,K+56)=AIMAG(GF(K))
C
C    FOIL COMPONENTS FOR MATRICIES  -BOD AND BEV-
C
      BODF(1)=0.0
      BODF(2)=+REAL(GF(3))
      BODF(3)=+REAL(GF(5))
      BODF(4)=0.0
      BODF(5)=-AIMAG(GF(3))
      BODF(6)=-AIMAG(GF(5))
      BEVF(1)=+REAL(GF(2))
      BEVF(2)=+REAL(GF(4))
      BEVF(3)=+REAL(GF(6))
      BEVF(4)=-AIMAG(GF(2))
      BEVF(5)=-AIMAG(GF(4))
      BEVF(6)=-AIMAG(GF(6))
      RETURN
  999 END
```

```
      SUBROUTINE THEO(XK1,CK)
      COMPLEX CK
 1001 FORMAT(*      J0    IER=*,I2)
 1002 FORMAT(*      J1    IER=*,I2)
 1003 FORMAT(*      Y0    IER=*,I2)
 1004 FORMAT(*      Y1    IER=*,I2)
      CALL IBESJ(XK1,0,XJ0,1.E-6,IER)
      IF(IER.GE.3) GO TO 77
      CALL IBESJ(XK1,1,XJ1,1.E-6,IER)
      IF(IER.GE.3) GO TO 78
      CALL IBESY(XK1,0,Y0,IER)
      IF(IER.EQ.3) GO TO 79
      CALL IBESY(XK1,1,Y1,IER)
      IF(IER.EQ.3) GO TO 80
      T1=XJ1+Y0
      T2=Y1-XJ0
      X=XJ1*T1+Y1*T2
      Y=-Y1*Y0-XJ1*XJ0
      CK=CMPLX(X,Y)
      X=T1*T1+T2*T2
      CK=CK/X
      GO TO 81
   77 WRITE(6,1001) IER
      GO TO 81
   78 WRITE(6,1002) IER
      GO TO 81
   79 WRITE(6,1003) IER
      GO TO 81
   80 WRITE(6,1004) IER
   81 RETURN
      END
```

```
      SUBROUTINE EXCIT(XK3,XK1,CK,EXL,EXM)
      COMPLEX CK,T1,T2,T3,T4,EXL,EXM,V
 1001 FORMAT(*      J0    IER=*,I2)
 1002 FORMAT(*      J1    IER=*,I2)
 1003 FORMAT(*      J2    IER=*,I2)
 1004 FORMAT(*      J3    IER=*,I2)
      IF(XK3) 2,3,3
    2 ISIGN=0
      GO TO 4
    3 ISIGN=1
    4 XK3=ABS(XK3)
      CALL IBESJ(XK3,0,XJ0,1.E-4,IER)
      IF(IER.GE.3) GO TO 77
      CALL IBESJ(XK3,1,XJ1,1.E-6,IER)
      IF(IER.GE.3) GO TO 78
      CALL IBESJ(XK3,2,XJ2,1.E-6,IER)
      IF(IER.GE.3) GO TO 79
      CALL IBESJ(XK3,3,XJ3,1.E-6,IER)
      IF(IER.GE.3) GO TO 80
      IF(ISIGN) 5,5,6
    5 XJ1=-XJ1
      XJ3=-XJ3
      XK3=-XK3
    6 T1=CMPLX(XJ0,-XJ1)
      T2=T1*CK
      R1=0.5*XK1*(XJ0+XJ2)
      T3=CMPLX(0.,R1)
      EXL=T2+T3
      T1=XJ0*CK
      T2=XJ1*(1.-CK)
      V=CMPLX(0.,1.)
      T2=V*T2
      R1=(XJ1+XJ3)*(XK1/4.)
      T3=CMPLX(R1,0.)
      T4=CMPLX(XJ2,0.)
      EXM=T1+T2-T3+T4
      GO TO 81
   77 WRITE(6,1001) IER
      GO TO 81
   78 WRITE(6,1002) IER
      GO TO 81
   79 WRITE(6,1003) IER
      GO TO 81
   80 WRITE(6,1004) IER
   81 RETURN
      END
```

```
C
C------VERSION 4  -  CDC 6700  -  L O A D S  -  JUNE, 1972-------------
C
      SUBROUTINE LOADS
     COMMON AM(27),NUT,NMAS,NOS,ST(25),DS(25),EL,ELL,X(25,8),Y(25,8),PM
    1AS(27),XMAS(27),ZMAS(27),RRG(27),XG,ZG,TMAS,EI44,EI55,EI66,EI46,TP
    2ST,RF33,RM35,RM55,DGM,DIP,K,N,TVOL,ALFA(40,11),BETA(40,11),HDG(10)
    3,FN(5),BAM(30),CDG(10),SDG(10),OMAX,OMIN,NFR,NOK,NOB,NOH,OMEN(40),
    4FR(7,6),XX(25,7),YY(25,7),DEL(25,7),SNE(25,7),CSE(25,7),EN1(25,7),
    5UN,OMEGA,ID,TITO(12),WORD,NON,IXAST,HDG1(10),IT,CBV,CHC,PRNTOP
     COMMON ST1(27),YMAS(27),BEAM,DRAFT,DMAX,IRR,ML,IEND,IBILGE,IPRES,
    2VNY,GRAV,AMODL,MOD,AKEELL,BEAMKL,ITS(25),RD(25),RFD(25),DELTAD(25)
    2,RKD(25),SD(25),COSPHD(25),PHID(25),STPR(25),IHMD(50)
     COMMON NWSTP,INWSTP(12)
      COMMON /TEMP/ PDFR(6,25),PDFI(6,25),RMO(6,30),AIMO(6,30),
    2 DA1(11),DB1(11),PEXR(6,25),PEXI(6,25),DADS(10,26),DDDS(10,26),
    2 TDA(6,6),TDB(6,6),SRF33(27),SRM35(27),SRM55(27),SC44(27),
    2 PAV(25,7,6),PAA(25,7,6),DA(6,6),DB(6,6),TEV(6,6),BEV(6,1),
    2 TOD(6,6),BOD(6,1),INDEX(6,3),AR1(42),AR2(42),AT1(42),AT2(42),
    2 VD(25),SBKD(27),EDDY(27),RGB(27),PRERE(8,14),PREIM(8,14),
    2 FZRSG(25),BVRSG(25),BVISG(25),FZISG(25),FYRSG(25),FYISG(25),
    2 TMRSG(25),TMISG(25),BLRSG(25),BLISG(25),RHMD(50),WE(30),ZN(30),
    2 XL1LMD(30),IHMD(50),WAVAMP(30),DUM4(76)
      COMMON /TMP1/ FACT,JJ,DM1(5),LL,GXI
      COMMON /TMP3/ RLO(5,30,25),AILO(5,30,25),STATN(24)
C
C     AFTER FIRST CALCULATING THE ADDED-MASS AND DAMPING FOR EACH SECTION
C     THE SHEARING FORCES AND BENDING AND TORSIONAL MOMENTS ARE DETERMINE
C
      DO 16 K=1,NOS
      DIP=ST(K)-TPST
      DO 54 I=1,NON
      FR(I,1)=EN1(K,I)
      FR(I,2)=-SNE(K,I)
      FR(I,3)=CSE(K,I)
      FR(I,4)=XX(K,I)*CSE(K,I)-YY(K,I)*FR(I,2)
      FR(I,5)=-DIP*FR(I,3)
      FR(I,6)=DIP*FR(I,2)
   54 CONTINUE
      DO 55  LK=1,10
      GO TO(613,613,613,613,613,613,614,615,616,617),LK
  613 CONTINUE
      L=LK
      M=LK
      GO TO 618
  614 CONTINUE
      L=5
      M=3
      GO TO 618
  615 CONTINUE
      L=2
      M=6
      GO TO 618
  616 CONTINUE
      L=2
      M=4
      GO TO 618
  617 CONTINUE
      L=6
      M=4
  618 CONTINUE
      DADS(LK,K)=0.0
      DDDS(LK,K)=0.0
      DO 619 J=1,NON
      DADS(LK,K)=DADS(LK,K)+DEL(K,J)*FR(J,L)*PAA(K,J,M)
      DDDS(LK,K)=DDDS(LK,K)+DEL(K,J)*FR(J,L)*PAV(K,J,M)
```

```
  619 CONTINUE
      DADS(LK,K)=2.0*DADS(LK,K)*DS(K)
      DDDS(LK,K)=2.0*DDDS(LK,K)*DS(K)
   55 CONTINUE
      DO 620 L=1,10
      DADS(L,K)=DADS(L,K)/TVOL/UN
      DDDS(L,K)=DDDS(L,K)/TVOL/SQRT(UN)*SQRT(2.)
  620 CONTINUE
      DO 621 L=4,10
      DADS(L,K)=DADS(L,K)*0.5*0.5
      DDDS(L,K)=DDDS(L,K)*0.5*0.5
  621 CONTINUE
      DO 622 L=7,9
      DADS(L,K)=DADS(L,K)*2.
      DDDS(L,K)=DDDS(L,K)*2.
  622 CONTINUE
   16 CONTINUE
C
C     THE POSSIBILITY THAT THERE MAY BE MASS FORWARD OF THE F.P. IS NOW
C     ACCOUNTED FOR.
C
      NOS1=NOS+1
      DA(2,2)=PMAS(NOS1)/TMAS*(-GXI**2)
      DA(2,4)=-ZMAS(NOS1)/ELL*PMAS(NOS1)/TMAS*(-GXI**2)
      DA(2,6)=XMAS(NOS1)*DA(2,2)/ELL
      DA(3,3)=DA(2,2)
      DA(3,5)=-DA(2,6)
      DA(4,2)=DA(2,4)
      ZD2=ZMAS(NOS1)**2
      DA(4,4)=PMAS(NOS1)/TMAS*(ZD2+RRG(NOS1)**2)/ELL/ELL*(-GXI**2)
      DA(4,6)=XMAS(NOS1)/ELL*DA(4,2)
      DA(6,2)=DA(2,6)
      DA(6,4)=DA(4,6)
      DA(6,6)=(PMAS(NOS1)/TMAS*(XMAS(NOS1)/ELL)**2)*(-GXI**2)
      DA(6,6)=DA(6,6)+PMAS(NOS1)/TMAS*(YMAS(NOS1)/ELL)**2*(-GXI**2)
      DA(5,3)=DA(3,5)
      DA(5,5)=PMAS(NOS1)/TMAS*(ZD2+XMAS(NOS1)**2)/ELL/ELL*(-GXI**2)
      FYR=-DA(2,2)*BEV(1,1)-DA(2,4)*BEV(2,1)-DA(2,6)*BEV(3,1)
      FYI=-DA(2,2)*BEV(4,1)-DA(2,4)*BEV(5,1)-DA(2,6)*BEV(6,1)
      FZR=-DA(3,3)*BOD(2,1)-DA(3,5)*BOD(3,1)
      FZI=-DA(3,3)*BOD(5,1)-DA(3,5)*BOD(6,1)
      BLR=-DA(6,2)*BEV(1,1)-DA(6,4)*BEV(2,1)-DA(6,6)*BEV(3,1)
      BLI=-DA(6,2)*BEV(4,1)-DA(6,4)*BEV(5,1)-DA(6,6)*BEV(6,1)
      DA(5,1)=(ZMAS(NOS1)/ELL*PMAS(NOS1)/TMAS)*(-GXI**2)
      BVR=-DA(5,3)*BOD(2,1)-DA(5,5)*BOD(3,1)-DA(5,1)*BOD(1,1)
      BVI=-DA(5,3)*BOD(5,1)-DA(5,5)*BOD(6,1)-DA(5,1)*BOD(4,1)
      TMR=-DA(4,2)*BEV(1,1)-DA(4,4)*BEV(2,1)-DA(4,6)*BEV(3,1)
      TMI=-DA(4,2)*BEV(4,1)-DA(4,4)*BEV(5,1)-DA(4,6)*BEV(6,1)
      NOSM1=NOS-1
      NOS2=NOS+2
      DO 53 K=1,NOSM1
      PRF33=SRF33(K)
      PRM35=SRM35(K)
      PRM55=SRM55(K)
      PC44=SC44(K)
      DA(2,2)=(DADS(2,K)+PMAS(K)/TMAS)*(-GXI**2)
      DB(2,2)=DDDS(2,K)*GXI
      DA(2,4)=(-ZMAS(K)/ELL*PMAS(K)/TMAS+DADS(9,K))*(-GXI**2)
      DB(2,4)=DDDS(9,K)*GXI
      DA(2,6)=(DADS(8,K)+XMAS(K)/ELL*PMAS(K)/TMAS-FN(JJ)/GXI**2*DDDS(2,K
     1))*(-GXI**2)
      DB(2,6)=(DDDS(8,K)+FN(JJ)*DADS(2,K))*GXI
      DA(3,3)=(DADS(3,K)+PMAS(K)/TMAS)*(-GXI**2)
      DB(3,3)=DDDS(3,K)*GXI
      DA(3,5)=(DADS(7,K)-XMAS(K)/ELL*PMAS(K)/TMAS+FN(JJ)/GXI**2*DDDS(3,K
     1))*(-GXI**2)
```

```
      DB(3,5)=(DDDS(7,K)-FN(JJ)*DADS(3,K))*GXI
      DA(4,2)=(-ZMAS(K)/ELL*PMAS(K)/TMAS+DADS(9,K))*(-GXI**2)
      DB(4,2)=DDDS(9,K)*GXI
      ZD2=ZMAS(K)**2
      DA(4,4)=(PMAS(K)/TMAS*(ZD2+RRG(K)**2)/ELL/ELL+DADS(4,K))*(-GXI**2)
      DB(4,4)=DDDS(4,K)*GXI
      DB(4,4)=DB(4,4)+VD(K)*GXI+SBKD(K)*GXI
      DA(4,6)=(-PMAS(K)/TMAS*ZMAS(K)/ELL*XMAS(K)/ELL+DADS(10,K)-FN(JJ)/G
     1XI**2*DDDS(9,K))*(-GXI**2)
      DB(4,6)=(DDDS(10,K)+FN(JJ)*DADS(9,K))*GXI
      DA(4,4)=DA(4,4)+PMAS(K)/TMAS*(-ZMAS(K)/ELL)
      DA(6,2)=(XMAS(K)/ELL*PMAS(K)/TMAS+DADS(8,K)+FN(JJ)/GXI**2*DDDS(2,K
     1))*(-GXI**2)
      DB(6,2)=(DDDS(8,K)-FN(JJ)*DADS(2,K))*GXI
      DA(6,4)=(-PMAS(K)/TMAS*ZMAS(K)/ELL*XMAS(K)/ELL+DADS(10,K)+FN(JJ)/G
     1XI**2*DDDS(9,K))*(-GXI**2)
      DB(6,4)=(DDDS(10,K)-FN(JJ)*DADS(9,K))*GXI
      DA(6,6)=(PMAS(K)/TMAS*(XMAS(K)/ELL)**2+DADS(6,K)+(FN(JJ)/GXI)**2*D
     1ADS(2,K))*(-GXI**2)
      DA(6,6)=DA(6,6)+PMAS(K)/TMAS*(YMAS(K)/ELL)**2*(-GXI**2)
      DB(6,6)=(DDDS(6,K)+(FN(JJ)/GXI)**2*DDDS(2,K))*GXI
      DA(5,1)=(ZMAS(K)/ELL*PMAS(K)/TMAS)*(-GXI**2)
      DA(5,3)=(DADS(7,K)-XMAS(K)/ELL*PMAS(K)/TMAS-FN(JJ)/GXI**2*DDDS(3,K
     1))*(-GXI**2)
      DB(5,3)=(DDDS(7,K)+FN(JJ)*DADS(3,K))*GXI
      DA(5,5)=(PMAS(K)/TMAS*(ZD2+XMAS(K)**2)/ELL/ELL+DADS(5,K)+(FN(JJ)/G
     1XI)**2*DADS(3,K))*(-GXI**2)
      DB(5,5)=(DDDS(5,K)+(FN(JJ)/GXI)**2*DDDS(3,K))*GXI
      TDA(2,2)=(-FN(JJ)/GXI**2/DS(K)*(DDDS(2,K)+DDDS(2,K+1)))*(-GXI**2)
      TDB(2,2)=(FN(JJ)/DS(K)*(DADS(2,K)+DADS(2,K+1)))*GXI
      TDA(2,4)=(-FN(JJ)/GXI**2/DS(K)*(DDDS(9,K)+DDDS(9,K+1)))*(-GXI**2)
      TDB(2,4)=(FN(JJ)/DS(K)*(DADS(9,K)+DADS(9,K+1)))*GXI
      TDA(2,6)=(-FN(JJ)/GXI**2/DS(K)*(DDDS(8,K)+DDDS(8,K+1))-(FN(JJ)/GXI
     1)**2/DS(K)*(DADS(2,K)+DADS(2,K+1)))*(-GXI**2)
      TDB(2,6)=(FN(JJ)/DS(K)*(DADS(8,K)+DADS(8,K+1))-(FN(JJ)/GXI)**2/DS(
     1K)*(DDDS(2,K)+DDDS(2,K+1)))*GXI
      TDA(4,2)=TDA(2,4)
      TDB(4,2)=TDB(2,4)
      TDA(4,4)=(-FN(JJ)/GXI**2/DS(K)*(DDDS(4,K)+DDDS(4,K+1)))*(-GXI**2)
      TDB(4,4)=(FN(JJ)/DS(K)*(DADS(4,K)+DADS(4,K+1)))*GXI
      TDA(4,6)=(-FN(JJ)/GXI**2/DS(K)*(DDDS(10,K)+DDDS(10,K+1))-(FN(JJ)/G
     1XI)**2/DS(K)*(DADS(9,K)+DADS(9,K+1)))*(-GXI**2)
      TDB(4,6)=(FN(JJ)/DS(K)*(DADS(10,K)+DADS(10,K+1))-(FN(JJ)/GXI)**2/D
     1S(K)*(DDDS(9,K)+DDDS(9,K+1)))*GXI
      TDA(6,2)=(-FN(JJ)/GXI**2/DS(K)*(DDDS(8,K)+DDDS(8,K+1)))*(-GXI**2)
      TDB(6,2)=(FN(JJ)/DS(K)*(DADS(8,K)+DADS(8,K+1)))*GXI
      TDA(6,4)=(-FN(JJ)/GXI**2/DS(K)*(DDDS(10,K)+DDDS(10,K+1)))*(-GXI**2
     1)
      TDB(6,4)=(FN(JJ)/DS(K)*(DADS(10,K)+DADS(10,K+1)))*GXI
      TDA(6,6)=(-FN(JJ)/GXI**2/DS(K)*(DDDS(6,K)+DDDS(6,K+1))-(FN(JJ)/GXI
     1)**2/DS(K)*(DADS(8,K)+DADS(8,K+1)))*(-GXI**2)
      TDB(6,6)=(FN(JJ)/DS(K)*(DADS(6,K)+DADS(6,K+1))-(FN(JJ)/GXI)**2/DS(
     1K)*(DDDS(8,K)+DDDS(8,K+1)))*GXI
      TDA(3,3)=(-FN(JJ)/GXI**2/DS(K)*(DDDS(3,K)+DDDS(3,K+1)))*(-GXI**2)
      TDB(3,3)=(FN(JJ)/DS(K)*(DADS(3,K)+DADS(3,K+1)))*GXI
      TDA(5,3)=(-FN(JJ)/GXI**2/DS(K)*(DDDS(7,K)+DDDS(7,K+1)))*(-GXI**2)
      TDB(5,3)=(FN(JJ)/DS(K)*(DADS(7,K)+DADS(7,K+1)))*GXI
      TDA(3,5)=TDA(5,3)+(FN(JJ)/GXI)**2/DS(K)*(DADS(3,K)+DADS(3,K+1))*(-
     1GXI**2)
      TDB(3,5)=TDB(5,3)+(FN(JJ)/GXI)**2/DS(K)*(DDDS(3,K)+DDDS(3,K+1))*GX
     1I
      TDA(5,5)=(-FN(JJ)/GXI**2/DS(K)*(DDDS(5,K)+DDDS(5,K+1))+(FN(JJ)/GXI
     1)**2/DS(K)*(DADS(7,K)+DADS(7,K+1)))*(-GXI**2)
      TDB(5,5)=(FN(JJ)/DS(K)*(DADS(5,K)+DADS(5,K+1))+(FN(JJ)/GXI)**2/DS(
     1K)*(DDDS(7,K)+DDDS(7,K+1)))*GXI
      PVM=PEXR(5,K)-DA(5,1)*BOD(1,1)-DA(5,3)*BOD(2,1)-DA(5,5)*BOD(3,1)-D
```

```
1B(5,3)*BOD(5,1)-DB(5,5)*BOD(6,1)
 AIVM=PEXI(5,K)+DB(5,3)*BOD(2,1)+DB(5,5)*BOD(3,1)-DA(5,1)*BOD(4,1)-
1DA(5,3)*BOD(5,1)-DA(5,5)*BOD(6,1)
 RTM=PEXR(4,K)-DA(4,2)*BEV(1,1)-DA(4,4)*BEV(2,1)-DA(4,6)*BEV(3,1)-D
1B(4,2)*BEV(4,1)-DB(4,4)*BEV(5,1)-DB(4,6)*BEV(6,1)
 AITM=PEXI(4,K)+DB(4,2)*BEV(1,1)+DB(4,4)*BEV(2,1)+DB(4,6)*BEV(3,1)-
1DA(4,2)*BEV(4,1)-DA(4,4)*BEV(5,1)-DA(4,6)*BEV(6,1)
 RLM=PEXR(6,K)-DA(6,2)*BEV(1,1)-DA(6,4)*BEV(2,1)-DA(6,6)*BEV(3,1)-D
1B(6,2)*BEV(4,1)-DB(6,4)*BEV(5,1)-DB(6,6)*BEV(6,1)
 AILM=PEXI(6,K)+DB(6,2)*BEV(1,1)+DB(6,4)*BEV(2,1)+DB(6,6)*BEV(3,1)-
1DA(6,2)*BEV(4,1)-DA(6,4)*BEV(5,1)-DA(6,6)*BEV(6,1)
 RFY=PEXR(2,K)-DA(2,2)*BEV(1,1)-DA(2,4)*BEV(2,1)-DA(2,6)*BEV(3,1)-D
1B(2,2)*BEV(4,1)-DB(2,4)*BEV(5,1)-DB(2,6)*BEV(6,1)
 AIFY=PEXI(2,K)+DB(2,2)*BEV(1,1)+DB(2,4)*BEV(2,1)+DB(2,6)*BEV(3,1)-
1DA(2,2)*BEV(4,1)-DA(2,4)*BEV(5,1)-DA(2,6)*BEV(6,1)
 RFZ=PEXR(3,K)-DA(3,3)*BOD(2,1)-DA(3,5)*BOD(3,1)-DB(3,3)*BOD(5,1)-D
1B(3,5)*BOD(6,1)
 AIFZ=PEXI(3,K)+DB(3,3)*BOD(2,1)+DB(3,5)*BOD(3,1)-DA(3,3)*BOD(5,1)-
1DA(3,5)*BOD(6,1)
 FYR=FYR+RFY
 FYI=FYI+AIFY
 FZR=FZR+RFZ
 FZI=FZI+AIFZ
 BLR=BLR+RLM
 BLI=BLI+AILM
 BVR=BVR+RVM
 BVI=BVI+AIVM
 TMR=TMR+RTM
 TMI=TMI+AITM
 EVR= (PDFR(5,K)+PDFR(5,K+1))/2.-TDA(5,3)*BOD(2,1)-TDA(5,5)*BOD(3,1
1)-TDB(5,3)*BOD(5,1)-TDB(5,5)*BOD(6,1)
 EVI=(PDFI(5,K)+PDFI(5,K+1))/2.+TDB(5,3)*BOD(2,1)+TDB(5,5)*BOD(3,1)
1-TDA(5,3)*BOD(5,1)-TDA(5,5)*BOD(6,1)
 ETR=(PDFR(4,K)+PDFR(4,K+1))/2.-TDA(4,2)*BEV(1,1)-TDA(4,4)*BEV(2,1)
1-TDA(4,6)*BEV(3,1)-TDB(4,2)*BEV(4,1)-TDB(4,4)*BEV(5,1)-TDB(4,6)*BE
2V(6,1)
 ETI=(PDFI(4,K)+PDFI(4,K+1))/2.+TDB(4,2)*BEV(1,1)+TDB(4,4)*BEV(2,1)
1+TDB(4,6)*BEV(3,1)-TDA(4,2)*BEV(4,1)-TDA(4,4)*BEV(5,1)-TDA(4,6)*BE
2V(6,1)
 ELR=(PDFR(6,K)+PDFR(6,K+1))/2.-TDA(6,2)*BEV(1,1)-TDA(6,4)*BEV(2,1)
1-TDA(6,6)*BEV(3,1)-TDB(6,2)*BEV(4,1)-TDB(6,4)*BEV(5,1)-TDB(6,6)*BE
2V(6,1)
 ELI=(PDFI(6,K)+PDFI(6,K+1))/2.+TDB(6,2)*BEV(1,1)+TDB(6,4)*BEV(2,1)
1+TDB(6,6)*BEV(3,1)-TDA(6,2)*BEV(4,1)-TDA(6,4)*BEV(5,1)-TDA(6,6)*BE
2V(6,1)
 EYR=(PDFR(2,K)+PDFR(2,K+1))/2.-TDA(2,2)*BEV(1,1)-TDA(2,4)*BEV(2,1)
1-TDA(2,6)*BEV(3,1)-TDB(2,2)*BEV(4,1)-TDB(2,4)*BEV(5,1)-TDB(2,6)*BE
2V(6,1)
 EYI=(PDFI(2,K)+PDFI(2,K+1))/2.+TDB(2,2)*BEV(1,1)+TDB(2,4)*BEV(2,1)
1+TDB(2,6)*BEV(3,1)-TDA(2,2)*BEV(4,1)-TDA(2,4)*BEV(5,1)-TDA(2,6)*BE
2V(6,1)
 EZR=(PDFR(3,K)+PDFR(3,K+1))/2.-TDA(3,3)*BOD(2,1)-TDA(3,5)*BOD(3,1)
1-TDB(3,3)*BOD(5,1)-TDB(3,5)*BOD(6,1)
 EZI=(PDFI(3,K)+PDFI(3,K+1))/2.+TDB(3,3)*BOD(2,1)+TDB(3,5)*BOD(3,1)
1-TDA(3,3)*BOD(5,1)-TDA(3,5)*BOD(6,1)
 FYRS=FYR+EYR
 FYIS=FYI+EYI
 FZRS=FZR+EZR-PRF33*BOD(2,1)-PRM35*BOD(3,1)
 FZIS=FZI+EZI-PRF33*BOD(5,1)-PRM35*BOD(6,1)
 TMRS=TMR+ETR
 TMIS=TMI+ETI
 TMRS=TMRS-PC44*BEV(2,1)
 TMIS=TMIS-PC44*BEV(5,1)
 BLRS=BLR+ELR-(ST(K)-TPST+0.5*DS(K))*0.5*FYRS
 BLIS=BLI+ELI-(ST(K)-TPST+0.5*DS(K))*0.5*FYIS
 BVRS=BVR+EVR+(ST(K)-TPST+0.5*DS(K))*0.5*FZRS
```

```
      BVIS=BVI+EVI+(ST(K)-TPST+0.5*DS(K))*0.5*FZIS
      BVRS=BVRS-PRM35*BOD(2,1)-PRM55*BOD(3,1)
      BVIS=BVIS-PRM35*BOD(5,1)-PRM55*BOD(6,1)
      FAC=TVOL/8.*ELL/BEAM
      FYRS=FYRS*FAC
      FYIS=FYIS*FAC
      FZRS=FZRS*FAC
      FZIS=FZIS*FAC
      TMRS=TMRS*FAC
      TMIS=TMIS*FAC
      BLRS=BLRS*FAC
      BLIS=BLIS*FAC
      BVRS=BVRS*FAC
      BVIS=BVIS*FAC
      FYRSG(K)=FYRS
      FYISG(K)=FYIS
      TMRSG(K)=TMRS
      TMISG(K)=TMIS
      BLRSG(K)=BLRS
      BLISG(K)=BLIS
      FZRSG(K)=FZRS
      FZISG(K)=FZIS
      BVRSG(K)=BVRS
      BVISG(K)=BVIS
       RLO (1,LL,K) = FYRS
       AILO(1,LL,K) = FYIS
       RLO (2,LL,K) = FZRS
       AILO(2,LL,K) = FZIS
       RLO (3,LL,K) =TMRS
       AILO(3,LL,K) =TMIS
       RLO (4,LL,K) =BVRS
       AILO(4,LL,K) =BVIS
       RLO (5,LL,K) =BLRS
       AILO(5,LL,K) =BLIS
       STATN(K) = STI(K+1) + 0.5*DS(K+1)*10.
   53 CONTINUE
       RETURN
       END
C
C------VERSION 4  -  CDC 6700  -  E X C F M  -  JUNE, 1972--------------
C
       SUBROUTINE EXCFM
       COMMON DM1(1496),FN(5),BAM(30),DM3(23),NOK,DM4(1137),TITO(12),
     2 DM5(16),PRNTOP,DM6(356)
       INTEGER PRNTOP,H
       COMMON /TEMP/ DM7(4784),ZN(30),DM8(186)
       COMMON /TMP1/ FACT,JJ,HDIG1,VKNOTS,DM9(5)
       COMMON /TMP5/ BOV(30,6,2)
       DATA MIN /3HMIN/
       BACKSPACE 1
       CALL SEPART (1)
      L = 0
      N = 1
      IF (BAM(1) .LE. BAM(NOK)) L = NOK + 1
      IF (BAM(1) .LE. BAM(NOK)) N = - 1
       DO 5614 JH=1,2
       IF (JH .EQ. 1) H = 1
       IF (JH .EQ. 2) H = 6
       IF (H .EQ. 6 .AND. PRNTOP .EQ. MIN) GO TO 5614
       WRITE (H,5608) TITO,HDIG1,VKNOTS,FN(JJ)
 5608 FORMAT(41H1  EXCITING FORCES AND MOMENTS  ***      ,12A6,15X,3H***
     2///17X,9HHEADING =,F5.0,4H DEG,7X,12HSHIP SPEED =,F6.2,6H KNOTS/
     2 18X,15H(HEAD SEAS=180),9X,15HFROUDE NUMBER =,F7.4)
C------PRINT EXCITING FORCES AND MOMENTS--------------------------------
       WRITE (H,5610)
 5610  FORMAT (//47X,33HNONDIMENSIONAL TRANSFER FUNCTIONS//
```

```
     2 16X,13HSURGE FORCE /,8X,12HSWAY FORCE /,7X,13HHEAVE FORCE /,7X,
     2 13HROLL MOMENT /,6X,14HPITCH MOMENT /,8X,12HYAW MOMENT /,/7X,
     2 3(13X,7HM*G*R/L),3(13X,5HM*G*R,2X),/5X,6HWE(ND),
     2 6(20H  AMPL. RATIO  PHASE)/11X,6(16X,4HDEG )/)
       K = L
       DO 5612 LL=1,NOK
       K = K + N
       IF (JH .EQ. 2) GO TO 5604
C------COMPUTE AMPLITUDE AND PHASE---------------------------------------
       DO 5600 I=1,6
       RL = BDV(K,I,1)
       AI = BDV(K,I,2)
       BDV(K,I,1) = SQRT(RL**2 + AI**2)
 5600  BDV(K,I,2) = ATAN2D(AI,RL)
 5604  CONTINUE
       WRITE (H,5611) ZN(K),((BDV(K,I,J),J=1,2),I=1,6)
 5611  FORMAT (4X,F7.3,6(1PE13.4,0PF7.1))
 5612  CONTINUE
 5614  CONTINUE
       CALL SEPART (2)
       RETURN
       END
C
C-------VERSION 4  -  CDC 6700  -  M O T O U T  -  JUNE, 1972------------
C
      SUBROUTINE MOTOUT
C-----MOTION OUTPUT SUBROUTINE-------------------------------------------
C-----MOTIONS ARE SURGE (X1), SWAY (X2), HEAVE (X2), ROLL (X4),----------
C-----PITCH (X5), YAW (X6)-----------------------------------------------
       INTEGER PRNTOP,H
       COMMON DM1(81),ELL,DM2(1414),FN(5),BAM(30),DM3(23),NOK,DM4(1137),
     2 TITO(12),WORD,DM5(15),PRNTOP,DM6(344),INWSTP(12)
       COMMON /TEMP/ DM7(300),RMO(6,30),AIMO(6,30),DM8(4094),WE(30),
     2 ZN(30),XLILMD(30),DM9(50),WAVAMP(30),DM0(76)
       COMMON /TMP1/ FACT,JJ,HDIGI,VKNOTS,WSLOPE,WSTP,IWSTP,DMA(2)
       COMMON /TMP2/ SHM(30,6,2)
       DATA MIN /3HMIN/
      DO 10 I=1,NOK
      WVLNTH = BAM(I)*ELL
C-----TERM1 SCALES NONDIMENSIONAL DISPLACEMENTS BY-
C                   WAVAMP
      TERM1 = WAVAMP(I)
C-----TERM2 SCALES NONDIMENSIONAL ANGLES BY-
C                   WAVAMP * 57.3 / WVLNTH
      TERM2 = TERM1*FACT/WVLNTH
      DO 10 J=1,6
C-----COMPUTE SINGLE AMPLITUDES-------------------------------------------
      TERM = TERM1
      IF (J .GT. 3) TERM = TERM2
      SHM(I,J,1) = TERM*SQRT(RMO(J,I)**2 + AIMO(J,I)**2)
C-----COMPUTE PHASES-----------------------------------------------------
      SHM(I,J,2) = ATAN2D(AIMO(J,I),RMO(J,I))
   10 CONTINUE
      L = 0
      N = 1
      IF (BAM(1) .LE. BAM(NOK)) L = NOK + 1
      IF (BAM(1) .LE. BAM(NOK)) N = - 1
       BACKSPACE 1
       CALL SEPART (1)
       DO 35 JH=1,2
      IF (JH .EQ. 1) H = 1
      IF (JH .EQ. 2) H = 6
      IF (H .EQ. 6 .AND. PRNTOP .EQ. MIN) GO TO 35
      WRITE (H,1000) TITO,HDIGI,VKNOTS,WSLOPE,FN(JJ),INWSTP(IWSTP)
C-----PRINT SINGLE AMPLITUDES--------------------------------------------
       WRITE (H,1010) (WORD,I=1,4)
```

```
      K = L
      DO 15 LL=1,NOK
      K = K + N
      WRITE (M,1020) WE(K),XL1LMD(K),BAM(K),ZN(K),WAVAMP(K),
     2(SHM(K,I,1),I=1,6)
   15 CONTINUE
       IF (M .EQ. 6) GO TO 35
      WRITE (1,1030)
      K = L
      DO 30 LL=1,NOK
      K = K + N
      WRITE (1,1040) WE(K),(SHM(K,I,2),I=1,6)
   30 CONTINUE
   35 CONTINUE
       CALL SEPART (2)
       IF (PRNTOP .EQ. MIN) GO TO 80
C-----PRINT RESPONSE AMPLITUDE OPERATORS--------------------------------
      WRITE (6,1050)
      K = L
      DO 50 LL=1,NOK
      K = K + N
      DO 40 I=1,6
      SHM(K,I,1) = SHM(K,I,1)/WAVAMP(K)
   40 SHM(K,I,1) = SHM(K,I,1)**2
      WRITE (6,1060) WE(K),((SHM(K,I,J),J=1,2),I=1,6)
   50 CONTINUE
C-----PRINT NONDIMENSIONAL TRANSFER FUNCTIONS---------------------------
      WRITE (6,1070)
      K = L
      WSCON = ELL/360.
      DO 70 LL=1,NOK
      K = K + N
      DO 60 I=1,6
      SHM(K,I,1) = SQRT(SHM(K,I,1))
      IF (I .GT. 3) SHM(K,I,1) = WSCON*SHM(K,I,1)/XL1LMD(K)
   60 CONTINUE
      WRITE (6,1060) XL1LMD(K),((SHM(K,I,J),J=1,2),I=1,6)
   70 CONTINUE
   80 CONTINUE
      RETURN
 1000 FORMAT(41H1SHIP MOTIONS IN REGULAR WAVES  ***       ,12A6,15X,3H***
     2///17X,*HEADING =*,F5.0,* DEG*,7X,*SHIP SPEED =*,F6.2,* KNOTS*,5X,
     2*WAVE SLOPE (360*,1H*,*R/LAMBDA), K*,1H*,*R, =*,F5.2,* DEG*/18X,
     2*(HEAD SEAS=180)*,9X,*FROUDE NUMBER =*,F7.4,7X,*WAVE STEEPNESS (2*
     21H*,*R/LAMBDA) = 1 /*I3)
 1010 FORMAT(//58X,17HSINGLE AMPLITUDES,
     2//6X,*  WE  L/LAM LAM/L WE(ND)   *
     2 *WAVE AMPL.(R)   SURGE(X1)      SWAY(X2)     HEAVE(X3)*
     2 *      ROLL(X4)      PITCH(X5)       YAW(X6)*,
     2 /7X,3HRPS,18X,4(7X,A6),10X,3HDEG,9X,3HDEG,11X,3HDEG/)
 1020 FORMAT(5X,2F6.3,F6.2,F7.3,2X,1P7E13.4)
 1030  FORMAT (//6X,*WE FS*,24X,*PHASES IN DEGREES*//)
 1040  FORMAT (4X,F7.3,6F10.3)
 1050 FORMAT (//50X,*RESPONSE AMPLITUDE OPERATORS*//
     2 15X,14H(SURGE / R)**2,7X,13H(SWAY / R)**2,6X,14H(HEAVE / R)**2,
     2 7X,13H(ROLL / R)**2,6X,14H(PITCH / R)**2,7X,12H(YAW / R)**2/
     26X,*  WE *,
     26(20H  AMPL. RATIO  PHASE)/7X,4HRPS ,6(20H    SQUARED     DEG )/)
 1060 FORMAT(4X,F7.3,6(1PE13.4,0PF7.1))
 1070  FORMAT (//47X,*NONDIMENSIONAL TRANSFER FUNCTIONS*//
     2 17X,9HSURGE / R,12X,8HSWAY / R,11X,9HHEAVE / R,11X,
     2 10HROLL / K*R,10X,11HPITCH / K*R,10X,9HYAW / K*R,
     2 /6X,*L/LAM*,6(20H  AMPL. RATIO  PHASE)/11X,6(16X,4HDEG )/)
       END
C
C------VERSION 4  -  CDC 6700  -  L O D O U T  -  JUNE, 1972------------
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C                                                                       LDO
      SUBROUTINE LODOUT (ISTAT)                                         LDO
C-----LOAD OUTPUT SUBROUTINE--------------------------------------------LDO
C-----LOADS ARE HORIZONTAL SHEAR FORCE (V2), VERTICAL SHEAR FORCE (V3),-LDO
C-----TORSIONAL MOMENT (V4), VERTICAL BENDING MOMENT (V5), HORIZONTAL---LDO
C-----BENDING MOMENT (V6)-----------------------------------------------LDO
       INTEGER PRNTOP,H                                                 LDO
       COMMON DM1(80),EL,ELL,DM2(510),TMAS,DM3(12),TVOL,DM4(890),FN(5), LDO
     2 BAM(30),DM5(23),NOK,DM6(1137),TITO(12),WORD,DM7(15),PRNTOP,      LDO
     2 DM8(54),BEAM,DM9(8),GRAV,DM90(280),INWSTP(12)                    LDO
       COMMON /TEMP/ DM0(4754),WE(30),ZN(30),XL1LMD(30),DMA(50),        LDO
     2 WAVAMP(30),DMB(76)                                               LDO
       COMMON /TMP1/ FACT,JJ,HDIG1,VKNOTS,WSLOPE,WSTP,IWSTP,DMC(2)      LDO
       COMMON /TMP2/ SLD(30,6,2)                                        LDO
       COMMON /TMP3/ RLO(5,30,25),AILO(5,30,25),STATN(24)               LDO
       COMMON /LODPRN/ DM10(24),WORD2,WORD3,DM11(263)                   LDO
       DATA MIN /3HMIN/                                                 LDO
      K = ISTAT                                                         LDO
C-----RO EQUALS SHIP MASS DIVIDED BY DISPLACED VOLUME-------------------LDO
       RO = TMAS/(TVOL*EL**3)                                           LDO
       CON = RO*GRAV*BEAM*ELL                                           LDO
      DO 10 I=1,NOK                                                     LDO
C-----TERM1 SCALES NONDIMENSIONAL FORCES BY-                            LDO
C                    RO * GRAV * BEAM * ELL * WAVAMP                    LDO
      TERM1 = WAVAMP(I)*CON                                             LDO
C-----TERM2 SCALES NONDIMENSIONAL MOMENTS BY-                           LDO
C                    RO * GRAV * BEAM * ELL * ELL * WAVAMP              LDO
      TERM2 = TERM1*ELL                                                 LDO
      DO 10 J=1,5                                                       LDO
C-----COMPUTE SINGLE AMPLITUDES FOR A PARTICULAR STATION----------------LDO
      TERM = TERM1                                                      LDO
      IF (J .GT. 2) TERM = TERM2                                        LDO
      SLD(I,J,1) = TERM*SQRT(RLO(J,I,K)**2 + AILO(J,I,K)**2)            LDO
C-----COMPUTE PHASES----------------------------------------------------LDO
      SLD(I,J,2) = ATAN2D(AILO(J,I,K),RLO(J,I,K))                       LDO
   10 CONTINUE                                                          LDO
      L = 0                                                             LDO
      N = 1                                                             LDO
      IF (BAM(1) .LE. BAM(NOK)) L = NOK + 1                             LDO
      IF (BAM(1) .LE. BAM(NOK)) N = - 1                                 LDO
       BACKSPACE 1                                                      LDO
       CALL SEPART (1)                                                  LDO
       DO 35 JH=1,2                                                     LDO
      IF (JH .EQ. 1) H = 1                                              LDO
      IF (JH .EQ. 2) H = 6                                              LDO
      IF (H .EQ. 6 .AND. PRNTOP .EQ. MIN) GO TO 35                      LDO
      WRITE (H,1000) TITO,HDIG1,VKNOTS,WSLOPE,FN(JJ),INWSTP(IWSTP)      LDO
C-----PRINT SINGLE AMPLITUDES-------------------------------------------LDO
      WRITE (H,1010) STATN(ISTAT),WORD,(WORD2,I=1,2),(WORD3,I=1,3)      LDO
      K = L                                                             LDO
      DO 15 LL=1,NOK                                                    LDO
      K = K + N                                                         LDO
      WRITE (H,1020) WE(K),XL1LMD(K),BAM(K),ZN(K),WAVAMP(K),            LDO
     2(SLD(K,I,1),I=1,5)                                                LDO
   15 CONTINUE                                                          LDO
       IF (H .EQ. 6) GO TO 35                                           LDO
      WRITE (1,1030)                                                    LDO
      K = L                                                             LDO
      DO 30 LL=1,NOK                                                    LDO
      K = K + N                                                         LDO
      WRITE (1,1040) WE(K),(SLD(K,I,2),I=1,5)                           LDO
   30 CONTINUE                                                          LDO
   35 CONTINUE                                                          LDO
       CALL SEPART (2)                                                  LDO
       IF (PRNTOP .EQ. MIN) GO TO 80                                    LDO
C-----PRINT RESPONSE AMPLITUDE OPERATORS--------------------------------LDO
```

```
      WRITE (6,1050)
      K = L
      DO 50 LL=1,NOK
      K = K + N
      DO 40 I=1,5
      SLD(K,I,1) = SLD(K,I,1)/WAVAMP(K)
   40 SLD(K,I,1) = SLD(K,I,1)**2
      WRITE (6,1060) WE(K),((SLD(K,I,J),J=1,2),I=1,5)
   50 CONTINUE
C-----PRINT NONDIMENSIONAL TRANSFER FUNCTIONS---------------------------
      WRITE (6,1070)
      K = L
      DO 70 LL=1,NOK
      K = K + N
      DO 60 I=1,5
      SLD(K,I,1) = SQRT(SLD(K,I,1))/CON
      IF (I .GT. 2) SLD(K,I,1) = SLD(K,I,1)/ELL
   60 CONTINUE
      WRITE (6,1060) XL1LMD(K),((SLD(K,I,J),J=1,2),I=1,5)
   70 CONTINUE
   80 CONTINUE
      RETURN
 1000 FORMAT(41H1   SEA LOADS IN REGULAR WAVES   ***       ,12A6,15X,3H***
     2///17X,*HEADING =*,F5.0,* DEG*,7X,*SHIP SPEED =*,F6.2,* KNOTS*,5X,
     2*WAVE SLOPE (360*,1H*,*R/LAMBDA), K*,1H*,*R, =*,F5.2,* DEG*/18X,
     2*(HEAD SEAS=180)*,9X,*FROUDE NUMBER =*,F7.4,7X,*WAVE STEEPNESS (2*
     21H*,*R/LAMBDA) = 1 /*I3)
 1010 FORMAT(//49X,*SINGLE AMPLITUDES   (STATION*,F6.2,1H),
     2//6X,*  WE  L/LAM LAM/L WE(ND)    *
     2 *WAVE AMPL.(R)  H.SHEAR(V2)  V.SHEAR(V3)    T.MOM.(V4)*
     2*    V.MOM.(V5)    H.MOM.(V6)*/7X,3HRPS,25X,A6,2(7X,A6),4X,
     2 3(3X,A8,2X)/)
 1020 FORMAT(5X,2F6.3,F6.2,F7.3,2X,1P7E13.4)
 1030  FORMAT (//6X,*WE FS*,24X,*PHASES IN DEGREES*//)
 1040  FORMAT (4X,F7.3,6F10.3)
 1050 FORMAT(//50X,28HRESPONSE AMPLITUDE OPERATORS//
     214X,*(H.SHEAR / R)*,2H**,*2    (V.SHEAR / R)*,2H**,*2     (T.MOM.*
     2* / R)*,2H**,*2      (V.MOM. / R)*,2H**,*2      (H.MOM. / R)*,3H**2/
     26X,*  WE *,
     25(20H   AMPL. RATIO  PHASE)/7X,4HRPS ,5(20H    SQUARED     DEG )/)
 1060 FORMAT(4X,F7.3,6(1PE13.4,0PF7.1))
 1070 FORMAT(//47X,33HNONDIMENSIONAL TRANSFER FUNCTIONS//
     214X,*H.SHEAR /             V.SHEAR /            T.MOM. /        *
     2*      V.MOM. /             H.MOM. /*/15X,2(2X,10HRO*G*B*L*R,8X),
     23(12HRO*G*B*L*L*R,8X)/6X,*L/LAM*
     25(20H  AMPL. RATIO  PHASE)/11X,5(16X,4HDEG )/)
      END
C
C------VERSION 4  -  CDC 6700  -  R C T A B L  -  JUNE, 1972
C
      SUBROUTINE RCTABL
       COMMON DM1(81),ELL,DM2(1414),FN(5),BAM(30),DM3(24),NOB,NOH,
     2 DM4(1150),HDG1(10),DM5(67),GRAV,DM6(229),THMD(50),NWSTP,
     2 INWSTP(12)
       COMMON /TEMP/ DM7(4844),IHMD(50),DM8(106)
       COMMON /TMP1/ FACT,DMP(8)
       COMMON /TMP4/ HMD(5,50,2),NHF,EPS
      WRITE (6,5500)
 5500 FORMAT (1H1,18X,32HROLL AMPLITUDE CONVERGENCE TABLE)
      KTH = 0
      DO 5340 I=1,NOH
      HDIG1 = HDG1(I)
      DO 5340 J=1,NOB
      VKNOTS = SQRT(ELL*GRAV)*FN(J)/1.689
      DO 5340 N=1,NWSTP
      KTH = KTH + 1
```

```
      WSTP = 1./FLOAT(INWSTP(N))
      WSLOPE = 180.*WSTP
     WRITE (6,5503) HDIG1,VKNOTS,FN(J),WSLOPE,INWSTP(N)
 5503 FORMAT (//,0H HEADING =,F5.0,
    220H DEG     SHIP SPEED =,F6.2,25H KNOTS     FROUDE NUMBER =,F7.4,
    216H    WAVE SLOPE =,F5.2,4H DEG,24H     WAVE STEEPNESS = 1 /,I3)
     ITERAT = IHMD(KTH)
     DO 5335 L=1,ITERAT
     K = L - 1
     THERAD = HMD(L,KTH,1)
     THCRAD = HMD(L,KTH,2)
     THEDEG = THERAD*FACT
     THCDEG = THCRAD*FACT
     THDRAD = ABS(THERAD - THCRAD)
     THDDEG = THDRAD*FACT
 5335 WRITE (6,5505) K,THERAD,THEDEG,THCRAD,THCDEG,THDRAD,THDDEG
 5505 FORMAT (12H0  ITERATION,I3,4X,17HROLL AMPL. EST. =,F7.4,
    26H RAD (,F5.2,5H DEG)/19X,17HROLL AMPL. CAL. =,F7.4,6H RAD (,F5.2,
    25H DEG)/19X,17H  DIFFERENCE     =,F7.4,6H RAD (,F5.2,5H DEG))
 5340 IF (ITERAT .EQ. 5 .AND. THDRAD .GT. EPS) WRITE (6,5510)
 5510 FORMAT (78H0JUST CAN NOT GET ROLL AMPLITUDE TO CONVERGE. FIVE ATTE
    2MPTS AND FIVE FAILURES./45H C-EST LA VIE. WILL TRY OTHER CONDITION
    2S NOW.)
     WRITE (6,5513)
 5513 FORMAT (//33H ROLL AMPLITUDE ESTIMATES (RAD) =)
     WRITE (6,5515) (THMD(I),I=1,NHF)
 5515 FORMAT (8F10.4)
      RETURN
      END
C
C------VERSION 4  -  CDC 6700  - T A N A K A  -  JUNE, 1972-------------
C
      SUBROUTINE TANAKA(THM,EDDY,RGB)
C
C PROGRAMMER- O. FALTINSEN,DNV
C
      COMMON AM(27),NUT,NMAS,NOS,ST(25),DS(25),EL,ELL,X(25,8),Y(25,8),PM
     1AS(27),XMAS(27),ZMAS(27),RRG(27),XG,ZG,TMAS,EI44,EI55,EI66,EI46,TP
     2ST,RF33,RM35,RM55,DGM,DIP,K,N,TVOL,ALFA(40,11),BETA(40,11),HDG(10)
     3,FN(5),BAM(30),CDG(10),SDG(10),OMAX,OMIN,NFR,NOK,NOB,NOH,OMEN(40),
     4FK(7,6),XX(25,7),YY(25,7),DEL(25,7),SNE(25,7),CSE(25,7),EN1(25,7),
     5UN,OMEGA,ID,TITO(12),WORD,NON,IXAST,HDG1(10),IT,CBV,CMC,PRNTOP
      COMMON ST1(27),YMAS(27),BEAM,DRAFT,DMAX,IRR,ML,IEND,IBILGE,IPRES,
     2VNY,GRAV,AMODL,MOD,AKEELL,BEAMKL,ITS(25),RD(25),RFD(25),DELTAD(25)
     2,RKD(25),SD(25),COSPHD(25),PHID(25),STPR(25),THMD(50)
      COMMON NWSTP,INWSTP(12)
      DIMENSION EDDY(27),RGB(27),F1(15),BDKG(15),GKDB(6),RFORE(6
     1),BAFT(5),CAFT(5),XI(8),YI(8)
      DIMENSION  ALF2(5),F2(5)
      ALF2(1)=0.0
      ALF2(2)=0.0873
      ALF2(3)=0.1745
      ALF2(4)=0.3491
      ALF2(5)=0.5235
      F2(1)=1.
      DO 1 I=1,5
      BDKG(I)=1./(60.-I*10.)
    1 CONTINUE
      BDKG(6)=1./5.
      DO 2  I=7,13
      BDKG(I)=0.5+0.5*(I-7)
    2 CONTINUE
      IF(THM-0.1745) 3,3,4
    3 CONTINUE
      F1(1)=0.455
      F1(2)=0.52
```

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      F1(3)=0.42
      F1(4)=0.35
      F1(5)=0.52
      GO TO 5
    4 CONTINUE
      IF(THM-0.2618)  6,6,7
    6 CONTINUE
      FAC=(THM-0.1745)/(0.2618-0.1745)
      F1(1)=(0.32-0.455)*FAC+0.455
      F1(2)=(0.34-0.52)*FAC+0.52
      F1(3)=(0.29-0.42)*FAC+0.42
      F1(4)=(0.31-0.35)*FAC+0.35
      F1(5)=(0.48-0.52)*FAC+0.52
      GO TO 5
    7 CONTINUE
      IF(THM-0.3491)  8,9,9
    8 CONTINUE
      FAC=(THM-0.2618)/(0.3491-0.2618)
      F1(1)=(0.25-0.32)*FAC+0.32
      F1(2)=(0.25-0.34)*FAC+0.34
      F1(3)=(0.22-0.29)*FAC+0.29
      F1(4)=(0.28-0.31)*FAC+0.31
      F1(5)=(0.45-0.48)*FAC+0.48
      GO TO 5
    9 CONTINUE
      F1(1)=0.25
      F1(2)=0.25
      F1(3)=0.22
      F1(4)=0.28
      F1(5)=0.45
    5 CONTINUE
      F1(6)=0.63
      F1(7)=0.63
      F1(8)=0.59
      F1(9)=0.53
      F1(10)=0.4
      F1(11)=0.35
      F1(12)=0.32
      F1(13)=0.3
      IF(THM-0.0873)  10,10,11
   10 CONTINUE
      AEX=10.6
      GO TO 12
   11 CONTINUE
      IF(THM-0.1745) 13,13,14
   13 CONTINUE
      AEX=(7.66-10.6)/(0.1745-0.0873)*(THM-0.0873)+10.6
      GO TO 12
   14 CONTINUE
      IF(THM-0.2618) 15,15,16
   15 CONTINUE
      AEX=(6.34-7.66)/(0.2618-0.1745)*(THM-0.1745)+7.66
      GO TO 12
   16 CONTINUE
      AEX=(5.28-6.34)/(0.3491-0.2618)*(THM-0.2618)+6.34
   12 CONTINUE
      GKDB(1)=1.2
      GKDB(2)=1.4
      GKDB(3)=1.6
      GKDB(4)=1.8
      GKDB(5)=2.0
      GKDB(6)=2.05
      RFORE(1)=1.0
      RFORE(2)=0.6
      RFORE(3)=0.34
      RFORE(4)=0.15
```

```
      RFORE(5)=0.04
      RFORE(6)=0.0
      BAFT(1)=1.0
      BAFT(2)=1.25
      BAFT(3)=1.5
      BAFT(4)=2.0
      BAFT(5)=2.25
      CAFT(1)=0.22
      CAFT(2)=0.24
      CAFT(3)=0.3
      CAFT(4)=0.5
      CAFT(5)=0.63
      DO 17  K=1,NOS
      ITSU=ITS(K)
      GO TO(18,19,20,21),ITSU
   18 CONTINUE
      RGB(K)=ABS(Y(K,NUT)*EL-ZG)
      IF(X(K,1))  60,60,61
   60 CONTINUE
      EDDY(K)=0.63
      GO TO 29
   61 CONTINUE
      GDB=RGB(K)/2./X(K,1)/EL
      IF(GDB-2.05) 22,23,23
   23 CONTINUE
      RBIL=0.0
      GO TO 24
   22 CONTINUE
      DO 25  J=2,6
       ITEMP = J
      IF(GDB-GKDB(J))  26,26,25
   25 CONTINUE
   26 CONTINUE
       J = ITEMP
      RBIL=(RFORE(J)-RFORE(J-1))/(GKDB(J)-GKDB(J-1))*(GDB-GKDB(J-1))+RFO
     1RE(J-1)
      RBIL=RBIL*X(K,1)*EL
   24 CONTINUE
      BDG=1./GDB
      DO 27  J=2,13
       ITEMP = J
      IF(BDG-BDKG(J)) 28,28,27
   27 CONTINUE
   28 CONTINUE
       J = ITEMP
      FONE=(F1(J)-F1(J-1))/(BDKG(J)-BDKG(J-1))*(BDG-BDKG(J-1))+F1(J-1)
      F2ALF=1.
      EDDY(K)=F2ALF*FONE*EXP(-AEX*RBIL/ABS(Y(K,NUT))/EL)
      GO TO 29
   19 CONTINUE
      DO 30 J=1,NUT
      XI(J)=X(K,J)*EL
      YI(J)=Y(K,J)*EL
   30 CONTINUE
      RBIL=RD(K)
      RGB(K)=SQRT((YI(NUT)-ZG)**2+XI(1)**2)-RBIL*(SQRT(2.)-1.)
      BDG=2.*XI(1)/ABS(YI(NUT)-ZG)
      DO 31 J=2,13
       ITEMP = J
      IF(BDG-BDKG(J)) 32,32,31
   31 CONTINUE
   32 CONTINUE
       J = ITEMP
      FONE=(F1(J)-F1(J-1))/(BDKG(J)-BDKG(J-1))*(BDG-BDKG(J-1))+F1(J-1)
      EDDY(K)=FONE*EXP(-AEX*RBIL/ABS(YI(NUT)))
      GO TO 29
```

```
20 CONTINUE
   RGB(K)=ABS(Y(K,NUT)*EL-ZG)
   BDG=2.*X(K,1)*EL/RGB(K)
   DO 33 J=2,5
    ITEMP = J
   IF(BDG-BAFT(J)) 34,34,33
33 CONTINUE
34 CONTINUE
    J = ITEMP
   EDDY(K)=(CAFT(J)-CAFT(J-1))/(BAFT(J)-BAFT(J-1))*(BDG-BAFT(J-1))+CA
  1FT(J-1)
   GO TO 29
21 CONTINUE
   RGB(K)=0.0
   EDDY(K)=0.0
29 CONTINUE
   GO TO(40,40,43,43),ITSU
40 CONTINUE
   IF(X(K,2)-X(K,1))  42,43,43
42 CONTINUE
   BR=(X(K,1)-X(K,2))/(-Y(K,2))
   ALF=ATAN(BR)
   RDD=RBIL/ABS(Y(K,NUT))/EL
   IF(RDD)  44,44,45
44 CONTINUE
   F2(2)=0.855
   F2(3)=0.765
   F2(4)=0.682
   F2(5)=0.646
   GO TO 46
45 CONTINUE
   IF(RDD-0.0571)  47,47,48
47 CONTINUE
   F2(2)=(0.745-0.855)/0.0571*RDD+0.855
   F2(3)=(0.670-0.765)/0.0571*RDD+0.765
   F2(4)=(0.745-0.682)/0.0571*RDD+0.682
   F2(5)=(0.915-0.646)/0.0571*RDD+0.646
   GO TO 46
48 CONTINUE
   IF(RDD-0.1142)  49,49,50
49 CONTINUE
   F2(2)=0.74
   F2(3)=(0.72-0.670)/(0.1142-0.0571)*(RDD-0.0571)+0.67
   F2(4)=(0.89-0.745)/(0.1142-0.0571)*(RDD-0.0571)+0.745
   F2(5)=(1.34-0.915)/(0.1142-0.0571)*(RDD-0.0571)+0.915
   GO TO 46
50 CONTINUE
   IF(RDD-0.1713)  51,51,52
51 CONTINUE
   F2(2)=(0.70-0.74)/(0.1713-0.1142)*(RDD-0.1142)+0.74
   F2(3)=0.72
   F2(4)=(1.20-0.89)/(0.1713-0.1142)*(RDD-0.1142)+0.89
   F2(5)=(1.94-1.34)/(0.1713-0.1142)*(RDD-0.1142)+1.34
   GO TO 46
52 CONTINUE
   F2(2)=0.7
   F2(3)=0.72
   F2(4)=1.2
   F2(5)=1.94
46 CONTINUE
   DO  53  J=2,5
    ITEMP = J
   IF(ALF-ALF2(J))  54,54,53
53 CONTINUE
54 CONTINUE
    J = ITEMP
```

```
      F2ALF=(F2(J)-F2(J-1))/(ALF2(J)-ALF2(J-1))*(ALF-ALF2(J-1))+F2(J-1)
      EDDY(K)=EDDY(K)*F2ALF
   43 CONTINUE
   17 CONTINUE
      RETURN
      END
C
C------VERSION 4  -  CDC 6700  - B I L G E K  -  JUNE, 1972-------------
C
      SUBROUTINE BILGEK(GXI,THM,SBKD,TBKD)
C
C PROGRAMMER- F.E. DE NOOIJ,DNV
C
      COMMON AM(27),NUT,NMAS,NOS,ST(25),DS(25),EL,ELL,X(25,8),Y(25,8),PM
     1AS(27),XMAS(27),ZMAS(27),RRG(27),XG,ZG,TMAS,EI44,EI55,EI66,EI46,TP
     2ST,RF33,RM35,RM55,DGM,DIP,K,N,TVOL,ALFA(40,11),BETA(40,11),HDG(10)
     3,FN(5),BAM(30),CDG(10),SDG(10),OMAX,OMIN,NFR,NOK,NOB,NOH,OMEN(40),
     4FR(7,6),XX(25,7),YY(25,7),DEL(25,7),SNE(25,7),CSE(25,7),EN1(25,7),
     5UN,OMEGA,ID,TITO(12),WORD,NON,IXAST,HDG1(10),IT,CBV,CMC,PRNTOP
      COMMON STI(27),YMAS(27),BEAM,DRAFT,DMAX,IRR,ML,IEND,IBILGE,IPRES,
     2VNY,GRAV,AMODL,MOD,AKEELL,BEAMKL,ITS(25),RD(25),RFD(25),DELTAD(25)
     2,RKD(25),SD(25),COSPHD(25),PHID(25),STPR(25),THMD(50)
      COMMON NWSTP,INWSTP(12)
C
C    THIS CALCULATION METHOD IS A MODIFICATION OF KATOS METHOD
C    R=RADIUS OF BILGE CIRCLE AT STATION K
C    RF=RISE OF FLOOR AT STATION K
C    DELTAL=LENGTH OF THAT PART OF THE BILGEKEEL WHICH IS AT STATION K
C    RK=DISTANCE OF MIDDLE OF BILGEKEEL  FROM THE MOMENTAXIS IN WATERPLA
C   S=LENGTH OF GIRTH  FROM  THE ROOT OF BILGEKEEL TO THE  WATERSURFACE
C                AT STATION K
C    COSPHI=COSINUS  TO THE ANGLE MADE BY THE PLANE OF BILGEKEEL WITH RK
C    PHI=ANGLE  BETWWEEN  RK  AND  WATERPLANE
C    BEAMKL=BREADTH OF BILGE KEEL
C    AKEEL=LENGTH OF BILGEKEEL
C
       DIMENSION  SBKD(27)
       DO 703  K=1,NOS
       R=RD(K)
       RF=RFD(K)
       DELTAL=DELTAD(K)
        IF (DELTAL .LE. 0.) GO TO 703
       RK=RKD(K)
       S=SD(K)
       COSPHI=COSPHD(K)
       PHI=PHID(K)
       SHBEAM=2.*X(K,1)*EL
       GK=ABS(Y(K,NUT))*EL
       T=6.283185*SQRT(ELL/GRAV)/GXI
       DRAUGT=GK
       TETAM=THM
       AKAPPA = R*(1.+RF/SHBEAM)**2./SQRT(0.5*SHBEAM*GK)
       CK =1.+3.5*EXP(-9.*AKAPPA)
       CO =1000.*(1.440+03.8*PHI**3.)
       ALABDA =   R/(DRAUGT-(RF/SHBEAM)*(SHBEAM-2.*R))
       FUNLAB = 1.34*  SIN(3.1416*ALABDA/3.6)/(1.+0.162* SIN(3.1416*(ALAB
      1DA-0.9)/1.8))
       EPSIL=ATAN(2.*RF/SHBEAM)
       Q =(0.5*SHBEAM *  TAN(3.1416/4. -EPSIL/2.)+RF-GK)*SIN(3.1416/4.+EP
      1SIL/2.)
       PO = GK - DRAUGT/3. - 2.* RF/3.
       PONE=0.88*(GK-DRAUGT-0.54*(SHBEAM/2.-(DRAUGT-RF)*TAN(3.1416/4.+EPS
      1IL/2.)))
       BCIRC = COSPHI + S*(Q+PO-(PO-PONE)*FUNLAB)/2./BEAMKL/RK
       ZETA = BEAMKL/(RK*PHI**.75)
       AN = 1.4 +2.03*EXP(-25.*ZETA)
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      ALPHA = 2.-AN
      REYN=8.*BEAMKL*RK*THM*GXI/ELL/ELL/VNY/6.2832*(AMODL/ELL)**2
      IF (REYN-10.**3) 10,10,11
   10 CA=1.95-0.25*ALOG(REYN)/ALOG(10.)+0.2*SIN(3.1416*(ALOG(REYN)/ALOG(
     110.)-2.19)/0.54)
      GO TO 7
   11 CA=1.
    7 CONTINUE
      F = RK*TETAM * PHI**1.70/(T *  SQRT(BEAMKL))
      FALFA= F**ALPHA
      CN = 1.98* EXP(-11.*BEAMKL/AKEELL)
      CS=CO/2.68/1000./FALFA
      SBKD(K)=GXI*2.*(RK/EL)**3*THM*2.*DELTAL*BEAMKL/ELL/ELL/3./3.141593
     1*CS*CA*CK*CN*BCIRC/TVOL
      SBKD(K)=2.*SBKD(K)
      TBKD=TBKD+SBKD(K)
  410 FORMAT(12E10.4)
  703 CONTINUE
      RETURN
      END
C
C------VERSION 4  -  CDC 6700  - E N D S E P  -  JUNE, 1972-------------
C
      SUBROUTINE ENDSEP(DA,DB,GXI,PAA,PAV,JJ)
C
C PROGRAMMER- O. FALTINSEN,DNV
C
      COMMON AM(27),NUT,NMAS,NOS,ST(25),DS(25),EL,ELL,X(25,8),Y(25,8),PM
     1AS(27),XMAS(27),ZMAS(27),RRG(27),XG,ZG,TMAS,EI44,EI55,EI66,EI46,TP
     2ST,RF33,RM35,RM55,DGM,DIP,K,N,TVOL,ALFA(40,11),BETA(40,11),HDG(10)
     3,FN(5),BAM(30),CDG(10),SDG(10),OMAX,OMIN,NFR,NOK,NOB,NOH,OMEN(40),
     4FR(7,6),XX(25,7),YY(25,7),DEL(25,7),SNE(25,7),CSE(25,7),EN1(25,7),
     5UN,OMEGA,ID,TITO(12),WORD,NON,IXAST,HDG1(10),IT,CBV,CMC,PRNTOP
      COMMON ST1(27),YMAS(27),BEAM,DRAFT,DMAX,IRR,ML,IEND,IBILGE,IPRES,
     2VNY,GRAV,AMODL,MOD,AKEELL,BEAMKL,ITS(25),RD(25),RFD(25),DELTAD(25)
     2,RKD(25),SD(25),COSPHD(25),PHID(25),STPR(25),THMD(50)
      COMMON NWSTP,INWSTP(12)
      DIMENSION DA(6,6),DB(6,6),PAA(25,7,6),PAV(25,7,6),DADS(10),DDDS(10
     1)
C
C  NOS IS TEMPORARILY CHANGED TO IXAST IN THIS ROUTINE
C
      NOSH=NOS
      NOS=IXAST
      DIP=ST(NOS)-TPST
      DO 54 I=1,NON
      FR(I,1)=EN1(NOS,I)
      FR(I,2)=-SNE(NOS,I)
      FR(I,3)=CSE(NOS,I)
      FR(I,4)=XX(NOS,I)*CSE(NOS,I)-YY(NOS,I)*FR(I,2)
      FR(I,5)=-DIP*FR(I,3)
      FR(I,6)=DIP*FR(I,2)
   54 CONTINUE
      DO 55 LK=1,10
      GO TO(613,613,613,613,613,613,614,615,616,617),LK
  613 CONTINUE
      L=LK
      M=LK
      GO TO 618
  614 CONTINUE
      L=5
      M=3
      GO TO 618
  615 CONTINUE
      L=2
      M=6
```

```
      GO TO 618
  616 CONTINUE
      L=2
      M=4
      GO TO 618
  617 CONTINUE
      L=6
      M=4
  618 CONTINUE
      DADS(LK)=0.0
      DDDS(LK)=0.0
      DO 619 J=1,NON
      DADS(LK)= DADS(LK)+DEL(NOS,J)*FR(J,L)*PAA(NOS,J,M)
      DDDS(LK)= DDDS(LK)+DEL(NOS,J)*FR(J,L)*PAV(NOS,J,M)
  619 CONTINUE
      DADS(LK)=2.0*DADS(LK)*DS(NOS)
      DDDS(LK)=2.0*DDDS(LK)*DS(NOS)
   55 CONTINUE
      DO 620 L=1,10
      DADS(L)=DADS(L)/IVOL/UN
      DDDS(L)=DDDS(L)/IVOL/SQRT(UN)*SQRT(2.)
  620 CONTINUE
      DO 621 L=4,10
      DADS(L)=DADS(L)*0.5*0.5
      DDDS(L)=DDDS(L)*0.5*0.5
  621 CONTINUE
      DO 622 L=7,9
      DADS(L)=DADS(L)*2.
      DDDS(L)=DDDS(L)*2.
  622 CONTINUE
      DA(2,2)=DA(2,2)-FN(JJ)/GXI**2/DS(NOS)*2.*DDDS(2)
      DB(2,2)=DB(2,2)+FN(JJ)/DS(NOS)*2.*DADS(2)
      DA(2,4)=DA(2,4)-FN(JJ)/GXI**2/DS(NOS)*2.*DDDS(9)
      DB(2,4)=DB(2,4)+FN(JJ)/DS(NOS)*2.*DADS(9)
      DA(2,6)=DA(2,6)-FN(JJ)/GXI**2/DS(NOS)*2.*DDDS(8)-(FN(JJ)/GXI)**2/D
     1S(NOS)*2.*DADS(2)
      DB(2,6)=DB(2,6)+FN(JJ)/DS(NOS)*2.*DADS(8)-(FN(JJ)/GXI)**2/DS(NOS)*
     12.*DDDS(2)
      DA(4,2)=DA(2,4)
      DB(4,2)=DB(2,4)
      DA(4,4)=DA(4,4)-FN(JJ)/GXI**2/DS(NOS)*DDDS(4)*2.
      DB(4,4)=DB(4,4)+FN(JJ)/DS(NOS)*2.*DADS(4)
      DA(4,6)=DA(4,6)-FN(JJ)/GXI**2/DS(NOS)*2.*DDDS(10)-(FN(JJ)/GXI)**2/
     1DS(NOS)*2.*DADS(9)
      DB(4,6)=DB(4,6)+FN(JJ)/DS(NOS)*2.*DADS(10)-(FN(JJ)/GXI)**2/DS(NOS)
     1*2.*DDDS(9)
      DA(6,2)=DA(6,2)-FN(JJ)/GXI**2/DS(NOS)*2.*DDDS(8)
      DB(6,2)=DB(6,2)+FN(JJ)/DS(NOS)*2.*DADS(8)
      DA(6,4)=DA(6,4)-FN(JJ)/GXI**2/DS(NOS)*2.*DDDS(10)
      DB(6,4)=DB(6,4)+FN(JJ)/DS(NOS)*DADS(10)*2.
      DA(6,6)=DA(6,6)-FN(JJ)/GXI**2/DS(NOS)*2.*DDDS(6)-(FN(JJ)/GXI)**2/D
     1S(NOS)*2.*DADS(8)
      DB(6,6)=DB(6,6)+FN(JJ)/DS(NOS)*2.*DADS(6)-(FN(JJ)/GXI)**2/DS(NOS)*
     12.*DDDS(8)
      DA(3,3)=DA(3,3)-FN(JJ)/GXI**2/DS(NOS)*2.*DDDS(3)
      DB(3,3)=DB(3,3)+FN(JJ)/DS(NOS)*2.*DADS(3)
      DA(5,3)=DA(5,3)-FN(JJ)/GXI**2/DS(NOS)*2*DDDS(7)
      DB(5,3)=DB(5,3)+FN(JJ)/DS(NOS)*2.*DADS(7)
      DA(3,5)=DA(3,5)+(FN(JJ)/GXI)**2/DS(NOS)*2.*DADS(3)-FN(JJ)/GXI**2/D
     1S(NOS)*2.*DDDS(7)
      DB(3,5)=DB(3,5)+(FN(JJ)/GXI)**2/DS(NOS)*2.*DDDS(3)+FN(JJ)/DS(NOS)*
     12.*DADS(7)
      DA(5,5)=DA(5,5)-FN(JJ)/GXI**2/DS(NOS)*2.*DDDS(5)+(FN(JJ)/GXI)**2/D
     1S(NOS)*2.*DADS(7)
      DB(5,5)=DB(5,5)+FN(JJ)/DS(NOS)*2.*DADS(5)+(FN(JJ)/GXI)**2/DS(NOS)*
     12.*DDDS(7)
```

```
      NOS=NOSH
      RETURN
      END
C
C------VERSION 4  -  CDC 6700  - H Y D P R E  -  JUNE, 1972-------------
C
      SUBROUTINE HYDPRE(WN,BOD,BEV,PAA,PAV,GXI,PRERE,PREIM,JJ,MM)
C
C PROGRAMMER- O. FALTINSEN,DNV
C
      COMMON AM(27),NUT,NMAS,NOS,ST(25),DS(25),EL,ELL,X(25,8),Y(25,8),PM
     1AS(27),XMAS(27),ZMAS(27),RRG(27),XG,ZG,TMAS,EI44,EI55,EI66,EI46,TP
     2ST,RF33,RM35,RM55,DGM,DIP,K,N,TVOL,ALFA(40,11),BETA(40,11),HDG(10)
     3,FN(5),BAM(30),CDG(10),SDG(10),OMAX,OMIN,NFR,NOK,NOB,NOH,OMEN(40),
     4FR(7,6),XX(25,7),YY(25,7),DEL(25,7),SNE(25,7),CSE(25,7),EN1(25,7),
     5UN,OMEGA,ID,TITO(12),WORD,NON,IXAST,HDG1(10),IT,CBV,CMC,PRNTOP
      COMMON ST1(27),YMAS(27),BEAM,DRAFT,DMAX,IRR,ML,IEND,IBILGE,IPRES,
     2VNY,GRAV,AMODL,MOD,AKEELL,BEAMKL,ITS(25),RD(25),RFD(25),DELTAD(25)
     2,RKD(25),SD(25),COSPHD(25),PHID(25),STPR(25),THMD(50)
      COMMON NWSTP,INWSTP(12)
      DIMENSION BOD(6,1),BEV(6,1),PAA(25,7,6),PAV(25,7,6),REP(1
     14,3),AIP(14,3),PRERE(8,14),PREIM(8,14)
      COMPLEX PDIFR,CPET,II
      COMPLEX PP,QQ,DODD,DEVEN
      II=(0.0,1.0)
      KPA=0
      DO 1 K1=1,NOS
      IF(STPR(K1))  2,1,2
    2 CONTINUE
      KM=K1-1
      KP=K1+1
      KPA=KPA+1
      DO 3 K=KM,KP
      CP=WN*(ST(K)-TPST)*CDG(MM)
      CP1=COS(CP)
      CP2=SIN(CP)
      CPET=(CP1+II*CP2)
      DIP=ST(K)-TPST
      DO 4 JS=1,2
      GO TO(5,6),JS
    5 CONTINUE
      CSP=1.0
      GO TO 7
    6 CONTINUE
      CSP=-1.0
    7 CONTINUE
      DO 8 J=1,NON
      FR(J,1)=EN1(K,J)
      FR(J,2)=-SNE(K,J)*CSP
      FR(J,3)=CSE(K,J)
      FR(J,4)= XX(K,J)*CSE(K,J)*CSP-YY(K,J)*FR(J,2)
      FR(J,5)=-DIP*FR(J,3)
      FR(J,6)=DIP*FR(J,2)
      PET=EXP(WN*YY(K,J))
      ARG=WN*XX(K,J)*CSP*SDG(MM)
      FC=COS(ARG)
      FS=SIN(ARG)
      PP=FR(J,3)
      PP=PP+II*FR(J,1)*CDG(MM)
      QQ=II*FR(J,2)*SDG(MM)
      DODD=(PP*FC+II*QQ*FS)*(GXI*SQRT(0.5*WN)/UN)
      DEVEN=(QQ*FC+II*PP*FS)*(GXI*SQRT(0.5*WN)/UN)
      PDIFR=-(DEVEN*CMPLX(PAA(K,J,2),PAV(K,J,2))*CSP*FR(J,2)+DODD*CMPLX(
     1PAA(K,J,3),PAV(K,J,3))*FR(J,3))*PET*CPET
      PDIFR=PDIFR-DODD*CMPLX(PAA(K,J,1),PAV(K,J,1))*FR(J,1)*PET*CPET
      RPDIF=REAL(PDIFR)
```

```
      AIPDF=AIMAG(PDIFR)
      REPMO=PAA(K,J,1)*BOD(1,1)+CSP*PAA(K,J,2)*BEV(1,1)+PAA(K,J,3)*BOD(2
     1,1)+0.5*(CSP*PAA(K,J,4)*BEV(2,1)+PAA(K,J,5)*BOD(3,1)+CSP*PAA(K,J,6
     2)*BEV(3,1))-PAV(K,J,1)*BOD(4,1)-CSP*PAV(K,J,2)*BEV(4,1)-PAV(K,J,3)
     3*BOD(5,1)-0.5*(CSP*PAV(K,J,4)*BEV(5,1)+PAV(K,J,5)*BOD(6,1)+CSP*PAV
     4(K,J,6)*BEV(6,1))
      AIPMO=PAV(K,J,1)*BOD(1,1)+CSP*PAV(K,J,2)*BEV(1,1)+PAV(K,J,3)*BOD(2
     1,1)+0.5*(CSP*PAV(K,J,4)*BEV(2,1)+PAV(K,J,5)*BOD(3,1)+CSP*PAV(K,J,6
     2)*BEV(3,1))+PAA(K,J,1)*BOD(4,1)+CSP*PAA(K,J,2)*BEV(4,1)+PAA(K,J,3)
     3*BOD(5,1)+0.5*(CSP*PAA(K,J,4)*BEV(5,1)+PAA(K,J,5)*BOD(6,1)+CSP*PAA
     4(K,J,6)*BEV(6,1))
      JM=J+NON*(JS-1)
      KKM=K-KM+1
      REP(JM,KKM)=RPDIF+REPMO
      AIP(JM,KKM)=AIPDF+AIPMO
    8 CONTINUE
    4 CONTINUE
    3 CONTINUE
      DO 9 JS=1,2
      GO TO(10,11),JS
   10 CONTINUE
      CSP=1.0
      GO TO 12
   11 CONTINUE
      CSP=-1.0
   12 CONTINUE
      K=K1
      DO 13 J=1,NON
      JM=J+(JS-1)*NON
      M=MM
      PRERE(KPA,JM)=REP(JM,2) -FN(JJ)/GXI/DS(K1)*(AIP(JM,3) -AIP(JM,1) )
     1+EXP(WN*YY(K,J))*COS(WN*(ST(K)-TPST)*CDG(MM)+CSP*WN*XX(K,J)*SDG(M)
     2)-(BOD(2,1)+CSP*XX(K,J)/2.*BEV(2,1)-0.5*(ST(K)-TPST)*BOD(3,1))
      PREIM(KPA,JM)=AIP(JM,2) +FN(JJ)/GXI/DS(K1)*(REP(JM,3) -REP(JM,1) )
     1+EXP(WN*YY(K,J))*SIN(WN*(ST(K)-TPST)*CDG(MM)+CSP*WN*XX(K,J)*SDG(M)
     2)-(BOD(5,1)+CSP*XX(K,J)/2.*BEV(5,1)-0.5*(ST(K)-TPST)*BOD(6,1))
   13 CONTINUE
    9 CONTINUE
    1 CONTINUE
      RETURN
      END
C
C------VERSION 4  -  CDC 6700  - P R E S T  -  JUNE, 1972---------------
C
      SUBROUTINE     PREST(PRF33,PRM35,PRM55,PC44)
C
C PROGRAMMER- O. FALTINSEN,DNV
C
      COMMON AM(27),NUT,NMAS,NOS,ST(25),DS(25),EL,ELL,X(25,8),Y(25,8),PM
     1AS(27),XMAS(27),ZMAS(27),RRG(27),XG,ZG,TMAS,EI44,EI55,EI66,EI46,TP
     2ST,RF33,RM35,RM55,DGM,DIP,K,N,TVOL,ALFA(40,11),BETA(40,11),HDG(10)
     3,FN(5),BAM(30),CDG(10),SDG(10),OMAX,OMIN,NFR,NOK,NOB,NOH,OMEN(40),
     4FR(7,6),XX(25,7),YY(25,7),DEL(25,7),SNE(25,7),CSE(25,7),EN1(25,7),
     5UN,OMEGA,ID,TITO(12),WORD,NON,IXAST,HDG1(10),IT,CBV,CMC,PRNTOP
      COMMON ST1(27),YMAS(27),BEAM,DRAFT,DMAX,IRR,ML,IEND,IBILGE,IPRES,
     2VNY,GRAV,AMODL,MOD,AKEELL,BEAMKL,ITS(25),RD(25),RFD(25),DELTAD(25)
     2,RKD(25),SD(25),COSPHD(25),PHID(25),STPR(25),THMD(50)
      COMMON NWSTP,INWSTP(12)
      DIMENSION  SS(27),HBM(27),SHB(27),HSB(27)
      DIMENSION  HB3(27)
      NMAD=K+1
      NMUD=K+2
      HB3(1)=0.0
       SS(1) = ST1(1)/10.
      SS(NMUD)=ST(K)+0.5*DS(K)
      HBM(1)=0.0
```

```
      IF(K-NOS)  2,3,3
    2 CONTINUE
      HB3(NMUD)=2.*X(K,1)**3
      HBM(NMUD)=X(K,1)
      GO TO 4
    3 CONTINUE
      HBM(NMUD)=0.0
      HB3(NMUD)=0.0
    4 CONTINUE
      DO 1  J=2,NMAD
      IP1=J-1
      SS(J)=ST(IP1)
      HBM(J)=X(IP1,1)
      HB3(J)=2.*X(IP1,1)**3
    1 CONTINUE
      DO 5 J=1,NMUD
      SPD=SS(J)-TPST
      SHB(J)=SPD*HBM(J)
      HSB(J)=SPD*SHB(J)
    5 CONTINUE
      PPCM=SIMPUN(SS,HB3,NMUD)
      PCBV=0.5*SIMPUN(SS,AM,NMUD)/TVOL
      PC44=PCBV+PPCM/3.0/TVOL*0.5
      PRF33=4.0*SIMPUN(SS,HBM,NMUD)/TVOL
      PRM35=-2.0*SIMPUN(SS,SHB,NMUD)/TVOL
      PRM55=SIMPUN(SS,HSB,NMUD)/TVOL
      RETURN
      END
C
C------VERSION 4  -  CDC 6700  - V I S C  -  JUNE, 1972----------------
C
      SUBROUTINE VISC(GXI,VD,TVD,THM,EDDY,RGB)
C
C PROGRAMMER- O. FALTINSEN,DNV
C
      COMMON AM(27),NUT,NMAS,NOS,ST(25),DS(25),EL,ELL,X(25,8),Y(25,8),PM
     1AS(27),XMAS(27),ZMAS(27),RRG(27),XG,ZG,TMAS,EI44,EI55,EI66,EI46,TP
     2ST,RF33,RM35,RM55,DGM,DIP,K,N,TVOL,ALFA(40,11),BETA(40,11),HDG(10)
     3,FN(5),BAM(30),CDG(10),SDG(10),OMAX,OMIN,NFR,NOK,NOB,NOH,OMEN(40),
     4FR(7,6),XX(25,7),YY(25,7),DEL(25,7),SNE(25,7),CSE(25,7),EN1(25,7),
     5UN,OMEGA,ID,TI1U(12),WORD,NON,IXAST,HDG1(10),IT,CBV,CMC,PRNTOP
      COMMON ST1(27),YMAS(27),BEAM,DRAFT,DMAX,IRR,ML,IEND,IBILGE,IPRES,
     2VNY,GRAV,AMODL,MOD,AKEELL,BEAMKL,ITS(25),RD(25),RFD(25),DELTAD(25)
     2,RKD(25),SD(25),COSPHD(25),PHID(25),STPR(25),THMD(50)
      COMMON NWSTP,INWSTP(12)
      DIMENSION  VD(27)
      DIMENSION  EDDY(27)
      DIMENSION  RGB(27)
      DIMENSION  XI(8),YI(8)
C
C   THIS SUBROUTINE  CALCULATES SKIN-FRICTIONAL AND EDDYMAKING ROLL-DAMP
C
      PI=3.141593
      TVD=0.0
      DO 2 K=1,NOS
      RG=RGB(K)/EL
      PSUR=0.0
      DO 3  J=1,NON
      PSUR=PSUR+DEL(K,J)
    3 CONTINUE
      PSUR=PSUR*DS(K)*2.
      DO  11  J=1,NUT
      XI(J)=X(K,J)
      YI(J)=Y(K,J)
   11 CONTINUE
      SQAR=2.*ABS(SIMPUN(YI,XI,NUT))
```

```
      DK=ABS(Y(K,NUT))
      BMK=2.*BMAX(NUT,XI)
      CA=SQAR/BMK/DK
      RS=1./PI*((0.887+0.145*CA)*(1.7*DK+CA*BMK)+2.*ZG/EL)
      PMOAR=RS**3*PSUR
      PARM=RS**2
      RN=3.22/8./PI*GXI*PARM*THM**2/VNY*(AMODL/ELL)**2
      VA2=0.0
      GO TO(4,5),MOD
    5 CONTINUE
      VA2=0.014*RN**(-0.114)
    4 CONTINUE
      VA=1.328*RN**(-0.5)+VA2
      VD(K)=1./6./PI*PMOAR*THM*GXI/TVOL*VA
      VD(K)=VD(K)+1./6./PI*PSUR*RG**3*THM*GXI/TVOL*EDDY(K)
      VD(K)=2.*VD(K)
      TVD=TVD+VD(K)
    2 CONTINUE
      RETURN
      END
C
C------VERSION 4  -  CDC 6700  -  A T A N 2 D  -  JUNE, 1972------------
C
        FUNCTION ATAN2D (B,A)
C
C PROGRAMMER- W. MEYERS,NSRDC
C
C------ARCTANGENT FUNCTION TO COMPUTE ANGLES (IN DEGREES) IN ANY---------
C------QUADRANT.  THE B ARGUMENT IS THE IMAGINARY VECTOR.  THE A---------
C------ARGUMENT IS THE REAL VECTOR.-------------------------------------
C
        DATA EPS /1.E-10/
        IF (B .EQ. 0.) ATAN2D =  0.
        IF (B .GT. 0.) ATAN2D = 90.
        IF (B .LT. 0.) ATAN2D =-90.
        IF (ABS(A) .GT. EPS) ATAN2D = ATAN2(B,A)*57.295779
        RETURN
        END
C
C------VERSION 4  -  CDC 6700  - B M A X  -  JUNE, 1972-----------------
C
      FUNCTION BMAX(NUT,XI)
      DIMENSION XI(1)
      A=XI(1)
      IF (NUT .EQ. 1) GO TO 20
      DO 10 I=2,NUT
      IF(XI(I).GT.A) A=XI(I)
   10 CONTINUE
   20 BMAX=A
      RETURN
      END
```

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